SOME IMPORTANT ENGINEERING FEATURES

OF THE

CANADIAN PACIFIC RAILWAY

REPRINT OF A SERIES OF ARTICLES IN

THE CANADIAN ENGINEER

TORONTO, 1915

(PRINTED IN CANADA)

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The EDITH *and* LORNE PIERCE
COLLECTION *of* CANADIANA

Queen's University at Kingston

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FOREWORD

THE Dominion of Canada and the Canadian Pacific Railway have grown together through a period of thirty-five years. A history of the development of the one is substantially a history of the development of the other. Civilization and industry followed the pioneer line across the prairies and through the mountains to the Pacific coast. The owner of the pack horse in the early eighties looked askance at the intrusion of steel and steam. To predict then that in 1913 the C.P.R. would freight thirty million tons of produce would have been as sensational as to foretell a quarter of a billion bushels of wheat from the Canadian West in 1915. The march of science from the tallow dip to the incandescent lamp is not more remarkable than the development of the West. Meanwhile the rolling stock of the C.P.R has gathered no moss.

In any extensive railway system there are evidences aplenty of the significance and application of engineering. To the dual development referred to above, there is a striking similarity in, and dependency upon, the contemporaneous development of engineering design and construction. In its mountain tunnels, its bridges and viaducts, its ocean and interior terminals, and its locomotive and car shops, the Canadian Pacific Railway presents a criterion of the accomplishments of the engineer. The following brief descriptions of some of these features, together with a reference to the notable undertaking of the company in irrigating over 3,000,000 acres of prairie land in the Canadian wheat belt, are intended to illustrate in what great measure the engineering profession has lent of its masterful conceptions to the development of the world's greatest transcontinental railway.

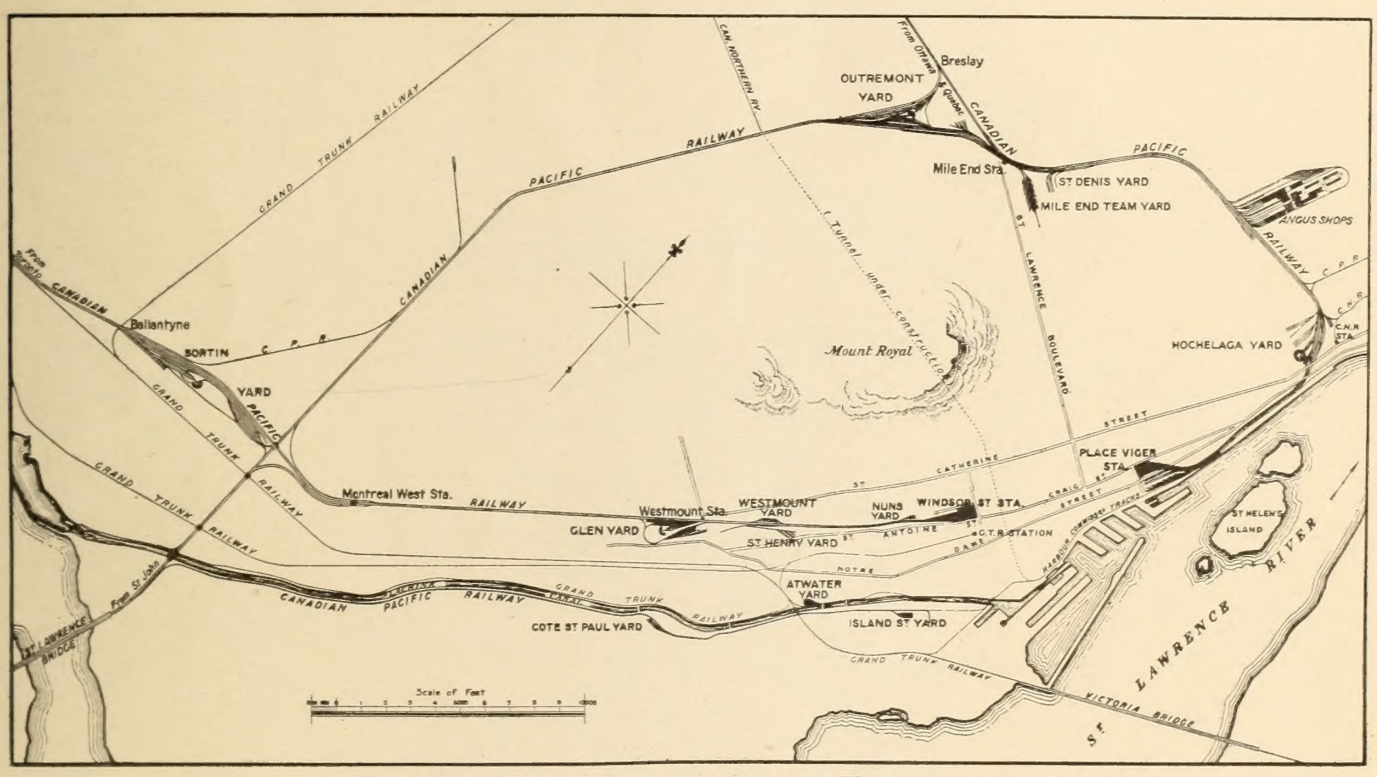
A NOTABLE GROUP OF RAILWAY TERMINALS

ILLUSTRATING BY DIAGRAM AND BRIEF DESCRIPTION THE OUTSTANDING FEATURES OF THE CANADIAN PACIFIC RAILWAY TERMINALS AT QUEBEC, MONTREAL, WINNIPEG AND VANCOUVER.

THE efficiency of a modern railway terminal is not manifested in bells and bustle. To perfect a terminal organization and management, efficient as well under ordinary conditions as when subjected to tests involving maximum demands and extreme conditions, is the greatest problem for the executive head of a busy transcontinental. Nowhere in the complexity of the business world is there greater justification for employing methods which have back of them principles harmonizing with the results of scientific study and research, toned down by the best skill that training and experience can command. Such a terminal must be the acme of organization, but it must first be well located and well arranged. A terminal system cannot be here to-day and there to-morrow to comply with the vicissitudes of restless traffic.

The Canadian Pacific Railway has stragetically located its more important terminals at St. John, Quebec, Montreal, Toronto, Fort William, Winnipeg and Vancouver. In a single year (1913) this railway earned nearly $90,000,000 from freight, and $35,500,000 from passenger traffic. Or, the standard of its terminal organizations is perhaps better illustrated by the manner in which it met the exacting demands created by the complete disorganization of business in 1914 and the necessity of economy arising out of depression and war. The rapidity and uniformity with which the company, in a few months, reduced maintenance and transportation expenses over its 12,900 miles of track, is one of the most remarkable evidences of terminal organization and management.

Thus, while a would-be but belated traveller may occasionally deign to recast, in a twinkle, the whole system, there is much to be learned from a study of the terminals that handle the major portion of Canada's long-haul traffic. Only a few will be referred to here: The eastern terminals at Montreal and Quebec, the terminal at Vancouver, where transcontinental trains connect with coastal and trans-Pacific steamers, and the Winnipeg yards, through which rolls an enormous volume of traffic between eastern and western Canada.



Canadian Pacific Railway Stations and Yards at Montreal.

C.P.R. Terminal at Montreal.

As the accompanying plan indicates, the tracks of the Canadian Pacific Railway very nearly surround the city of Montreal with main lines radiating to the north, west and south. The line to the north leads to Quebec, the Laurentian Mountains and Ottawa; the line to the west leads to Toronto and is at the same time the short line to Ottawa. The line to the south, which crosses the St. Lawrence River on the new double track bridge, leads to all points east and south on the C.P.R. on the southerly side of the St. Lawrence River.

Passenger trains for the east, south and west run from the Windsor Street station with stops in Montreal at Westmount and Montreal West. Trains for the north run from Place Viger with a stop at Mile End. The

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passenger equipment in the one case is handled at Glen Yard, which lies opposite Westmount station. In the other case the passenger engines are handled at Hochelaga yard and the other equipment in the Place Viger station and the adjacent coach yard.

The entire freight business in the Montreal terminals is handled in the three main yards: Outremont to the north, Sortin to the west and Hochelaga to the east. In addition, Sortin is the base yard for the territory between Montreal West and Windsor Street and for the territory on both sides of the Lachine Canal; Outremont yard for the northern and part of the eastern portion of the city and Hochelaga yard for the import and export business at the wharves and the Place Viger local freight terminal.

This local freight terminal is the main point from which both car-load and L.C.L. freight are distributed for the down-town district and is the largest single unit for either class of freight in the Montreal terminals.

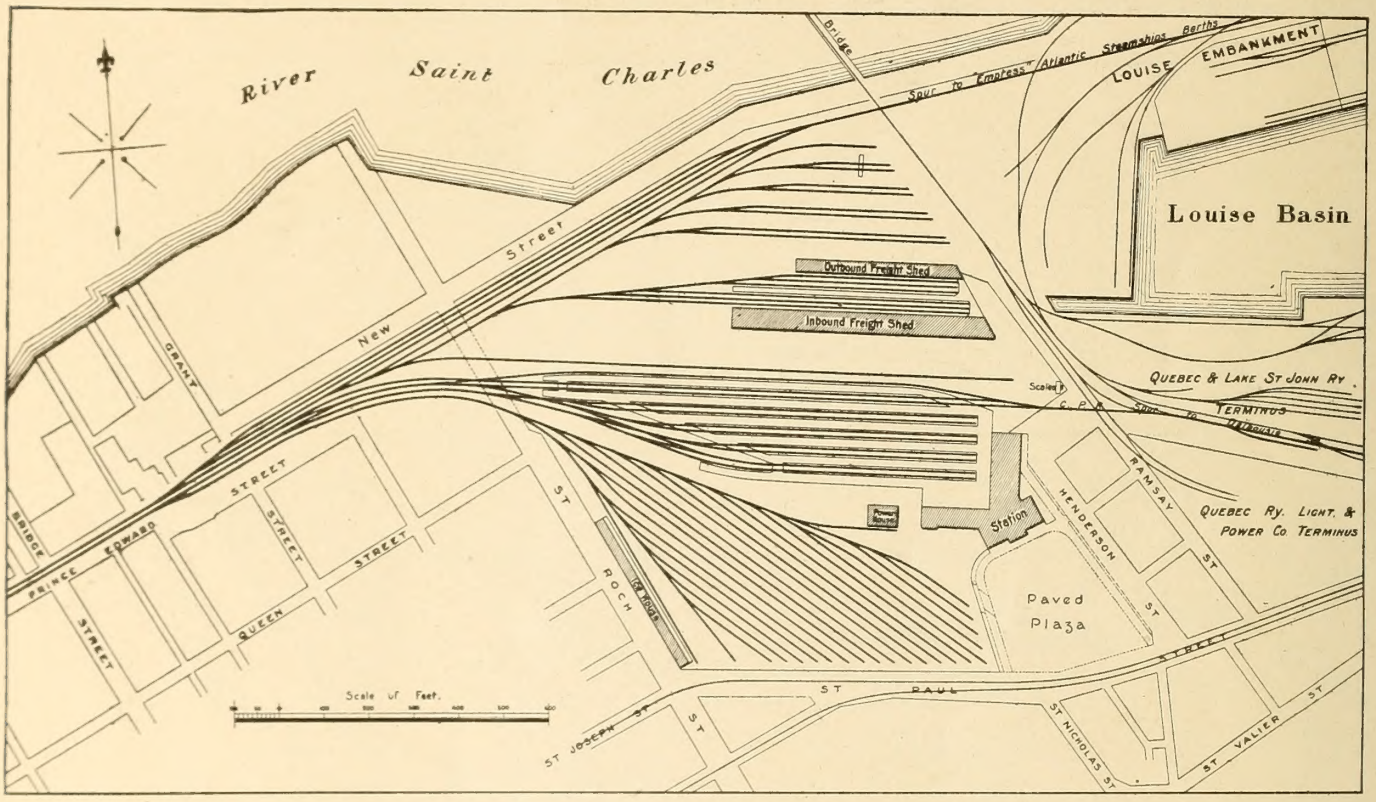
Other units are located in the easterly end of the city at Moreau Street, Iberville Street, St. Denis Street, Mile End and Park Avenue. The westerly end of the city is served by units at St. Henry, Westmount and Montreal West and by various yards along the north and south bank of the Lachine Canal which are tributary to what are known as the North and South Bank branches. The city has not yet developed sufficiently along the line between Montreal West and Outremont to warrant the construction of more than very minor local freight facilities through this territory.

The Angus shops lie adjacent to and north of the main line between Place Viger and Mile End.

The Quebec Terminals.

The plan of the terminal arrangements at Quebec, which appears herewith, is the result of an entire remodelling of both passenger and freight sections. This became a necessity on account of the growth of business during recent years, and on account also of their proposed use by both the Canadian Pacific Railway and the National Transcontinental Railway as a union terminal. The work, which was started during the summer of 1914, includes the construction of a new passenger station building and yard with the necessary adjoining coach yard, new freight sheds and team tracks, new engine facilities and main yard and a double track main line through the terminals. It is intended to have all this work completed by 1917.

The track leading to the Louise embankment and the Empress wharves is to be relocated further to the north. This permits of constructing a new and enlarged team yard in such a position that teams need not cross the heavy train movement to and from the wharves. This yard of about 105 cars capacity will be built chiefly on ground reclaimed from the St. Charles River.



The New Quebec Terminal of the C.P.R.

The new freight sheds are now complete and in service. The outbound shed is 30 ft. wide and 360 ft. long, while the inbound shed proper is 50 ft. wide and 460 ft. long; the balance of its length being given over to a two-story office building. Each shed is served by three tracks —the outbound having a capacity of 27 cars and the inbound a capacity of 39 cars, while a trucking platform between the two sets of tracks permits of their ready use for L.C.L transfer purposes. The sheds are so located that they may at any time in the future be increased in length as more capacity is required.

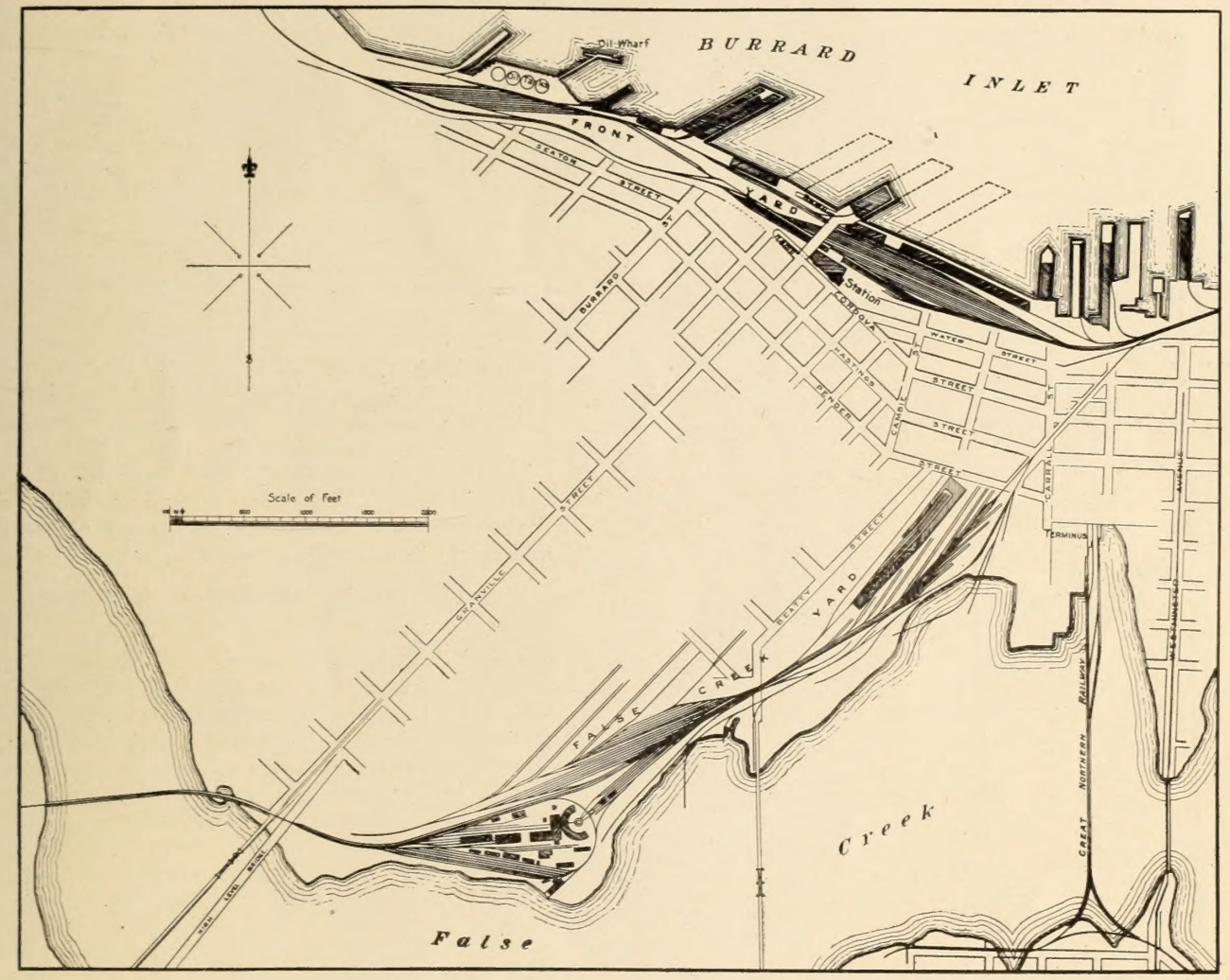
The new passenger station is now under construction, and will be in use early in the new year. The building is a most interesting adaptation of the Chateaus of the Loire in France, and has been specially designed by the architect to meet the requirements of the old and historic city of Quebec in this respect, as well as to amply fulfil the requirements of the present day and far future,

from the utilitarian point of view. The building is located on the site of the old freight sheds, its main entrance being on St. Paul Street. That portion of it facing on the proposed plaza, 200 ft x 300 ft. long, will be given over to ticket booths, baggage checking counters and similar public facilities. The waiting rooms will be in the north wing and the baggage, mail and express facilities in the west wing. The first floor will be devoted to the local offices of the Canadian Pacific Railway and also of the Transcontinental Railway.

The station yard will include, at the present time, eight stub end passenger tracks, varying in capacity from 7 to 10 cars and an engine, and three through tracks varying from 12 to 14 cars and an engine. The through tracks are providing for handling pilgrimage trains which run through to St. Anne de Beaupre. The tracks are arranged in pairs at 13-ft. centres with 18-ft. combination baggage and passenger platforms between the pairs. Space has been left for future additional tracks between the present stub tracks and the baggage wing of the station.

The coach yard will lie to the south of the station and have a capacity of 130 coaches. Its construction has not yet been undertaken as it is on the site of the present station and station yard which must be maintained in service until the new station is completed. The heating of this yard, the station and station yard and the freight sheds will all be handled from a central power house located just west of the baggage wing of the station. The ice house on St. Roch Street is intended to provide both for the railway requirements and the Chateau Frontenac.

The existing engine facilities which lie just to the west of Bridge Street, will be maintained in service until such time as the new and much more modern facilities can be constructed. The location of these new facilities has not yet been decided upon, but will be, in all probability, at a point some three or four miles from the Palais Grounds where it will be possible to build a freight terminal yard of a size and layout such as is required for handling both the local and export freight business. The double track will be constructed westwardly from the Palais Grounds and extend well beyond the new freight yard to the point where the joint C.P.R.-N.T.R. terminal ends.

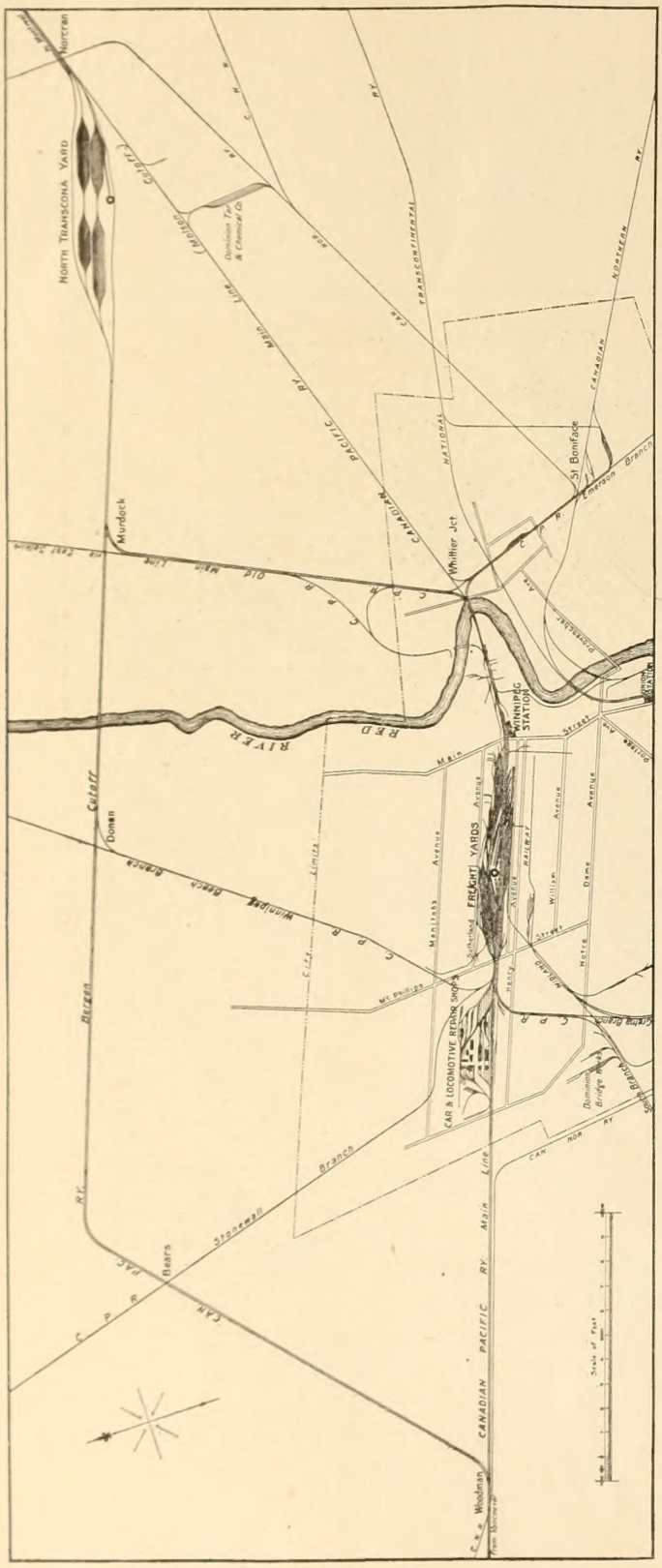


C.P.R. Ocean Terminal at Vancouver.

The Pacific Terminal at Vancouver.

The somewhat unusual arrangement, as illustrated by the accompanying plan of the Vancouver terminal situation, provides for the easy interchange of traffic between railway, steamship lines and the city itself. As compared with other large terminals, it is unusual also from the suburban traffic point of view. In Vancouver this is notable for its absence. The trains are not numerous, but they are long and are frequently run in sections. Moreover, they carry an unusual variety of traffic.

The present layout is the result of alterations commenced in 1912 and completed in July, 1914. The old passenger station built in 1898 at the foot of Granville Street, with offices, etc., at street level, and baggage



The Canadian Pacific Railway Yards at Winnipeg and Transcona.

room at track level 30 ft. below the street, was removed and an entirely new structure erected in its stead. This new station has its main entrance on Cordova Street, its baggage rooms, etc., on the lower floor, the two levels being connected by a complete elevator system. Passenger traffic between station and trains is carried over the tracks by a foot bridge directly connected with waiting rooms, and giving access to the track platforms, which are covered.

There are four through passenger tracks, two for incoming and two for outbound service, with provision for future additions. They lie between the station and the freight yard, at an elevation 5 ft. greater than that of the old track level, thereby reducing to about 25 ft. the difference between the floor levels in the station itself.

The freight yard was rearranged to advantageously connect with the present steamship piers, as well as those that will be constructed when future business requires.

Granville Street has been extended by viaduct over the tracks, affording access to the new steamship pier which comprises two levels. The viaduct itself is 80 ft. in width. The pier has a substructure of creosoted timber involving the use of about 3,000 piles ranging in length from 85 to 110 ft. The superstructure is of slow-burning timber construction. Its two levels are served by three tracks.

It will be noted that another viaduct carries Burrard Street over the terminal yard, giving access to the other piers previously built. There are two large sheds for the accommodation of trans-Pacific steamship traffic, and five sheds on adjoining wharves for the use of the coastal steamers of the C.P.R. The yard tracks extend along this harbor front for about 1½ miles.

The extensive alterations to the Vancouver terminal, briefly summarized above, were directly due to the rapid growth of terminal business which rendered the previous terminal facilities inadequate for service and costly in operation.

The Interior Terminal at Winnipeg.

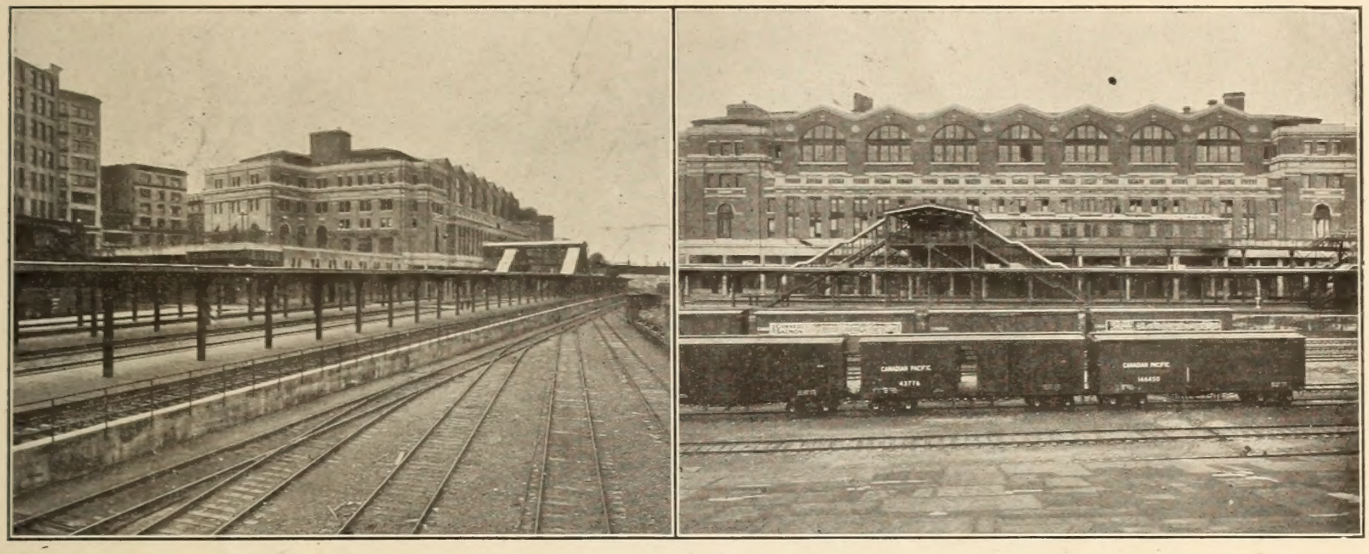
The Winnipeg yards of the C.P.R. have cleared practically all the traffic between Eastern and Western Canada. Considering the great increase in volume which this traffic has assumed during recent years, in addition to the potent railroad axiom that congested terminals mean excessive cost of handling traffic, it was to have been expected that sooner or later an extensive rearrangement of facilities would be necessary in Winnipeg, as in the several instances already cited. In May, 1913, improvements were commenced which have entailed an expenditure of about $2,500,000, and which are now nearing completion. They included alterations to station and platforms, in addition to considerable rearrangement of freight and passenger tracks. Associated with them, also, was the construction of an entirely new terminal at Transcona, a few miles distant, and of a double track cut-off around the city of Winnipeg.

The Winnipeg alterations were accomplished under some severe difficulties. City and railway traffic had to be maintained throughout. The subway which carries Main Street under the tracks was removed and replaced by a structure raising the tracks 6 ft. above the old level in order to do away with level crossings for the passengers in transit between train and waiting room. The Main Street subway, erected ten years ago, was of concrete reinforced by rails and heavy bars. Owing to a civic by-law prohibiting the use of explosives, the demolishment of the old structure was necessarily expensive and slow. Concrete was removed with the aid

of air drills and the reinforcing cut by oxy-acetylene blow pipes. Traffic was kept open on the tracks above during the operations of removing the old structure and building the new subway.

The present arrangement provides eight passenger tracks reached by subway and stairways, the former leading directly to the level of the street. It was found necessary, in order to secure head-room for the handling of passengers underneath the tracks, to lower a portion of the main waiting room. The entire north end was accordingly lowered about 4 ft. The baggage room has been moved from the extreme west of the building to the eastern end and under the elevated tracks. This department now faces Maple Street, a portion of which is used almost exclusively for the handling of baggage. A trucking subway running parallel to the tracks above and terminated by elevators, is a feature of the interesting arrangement of handling the baggage.

The improvements at Winnipeg included extensions to the Royal Alexandra Hotel.



The C.P.R. Station at Vancouver, Showing Separation of Freight and Passenger Tracks, Covered Bridge and Platforms.

NOTABLE C.P.R. TUNNELS IN BRITISH COLUMBIA

SPIRAL TUNNELS IN THE KICKING HORSE VALLEY—ROGER'S PASS TUNNEL THROUGH THE SELKIRK RANGE—TWO GRADE REDUCTION PROBLEMS ON THE MAIN LINE OF THE CANADIAN PACIFIC RAILWAY, AND THE METHODS OF THEIR SOLUTION.

ON October 21st, 1880, the Canadian Pacific Railway Company signed a contract with the Government of the Dominion of Canada to build a railway across the prairies and through the Rocky Mountains to the Pacific coast. The contract called for completion in ten years' time. This was deemed by many an out-and-out impossibility, owing to the topography of certain sections of the country and the inaccessible nature of the right-of-way for the supply of construction materials. By many, also, the project was pronounced a useless enterprise, to go down in history as one of the greatest blunders of the new Dominion. The country through which much of the railway would pass was believed by many to be a land "where nothing—not even a blade of corn—will ripen."

Fig. 1.—The Kicking Horse Valley Which the C.P.R. Follows Past Mount Stephen.

To the surmise regarding the engineering impossibility of the project within the time limit, it is a remarkable and equally creditable fact in the history of Canada that trains passed from tide-water to tide-water in November, 1885, and that during the year fixed for the completion of the contract, the line earned $20,000,000 for the builders. This latter accomplishment answers in a measure the traditional rumors of foolhardiness and blunder, as have likewise the annually increasing earnings of the company. During the past five years the gross earnings have amounted in round numbers to $10,500 per mile. The mileage of the line, as it stands at the present day, including branch services, amounts to 12,917 miles.

The speedy construction of the line in the early eighties necessitated a considerable amount of temporary work. The judgment of this has been fully warranted, first in the matter of early operation and later by a realization of a large saving in first cost and interest and a correspondingly large sum in ultimate cost.

It was to have been expected, therefore, that increasing trade, with its resultant changes to rolling stock and right-of-way, would see in the past thirty years many millions spent in grade reductions, in the erection of permanent structures and in the development of better terminal facilities. Those who have followed the railway development of Canada are fully aware that the Canadian Pacific Railway has outrun the railroads of older and more settled countries in this respect. It is with a view to calling attention in a cumulative sort of way to a few of the outstanding features of this track development that the present series of descriptive articles has been prepared. It is doubtful if there is in America a better illustration of what may be done in the way of grade reduction in mountainous regions than the improvement of the C.P.R. line in British Columbia. It has involved the construction, some six years ago, of one of the most interesting systems of tunnels in existence, and also the construction, now under way, of the longest tunnel on the continent. We refer in the former instance to the spiral tunnels in the valley of the Kicking Horse River, and in the latter to the Roger's Pass tunnel that is being driven through Mount Macdonald in the Selkirk Range.

Spiral Tunnels Between Hector and Field, B.C.

Prior to 1908 these two stations were separated by such extreme grades that four 154-ton consolidation (2-8-0) locomotives were required to haul a trainload of 710 tons of freight over this section of the main line. For

about three miles a grade of 4.5 per cent. prevailed, decreasing to 4 and 3.5 per cent. for the remainder of the distance. These grades involved the use of spring switches at different points along the line for the purpose of safety. Unless the engine-driver of a descending train signalled to the switchman that his train was under control, the normal setting of one of these switches would divert the train to a catch siding.

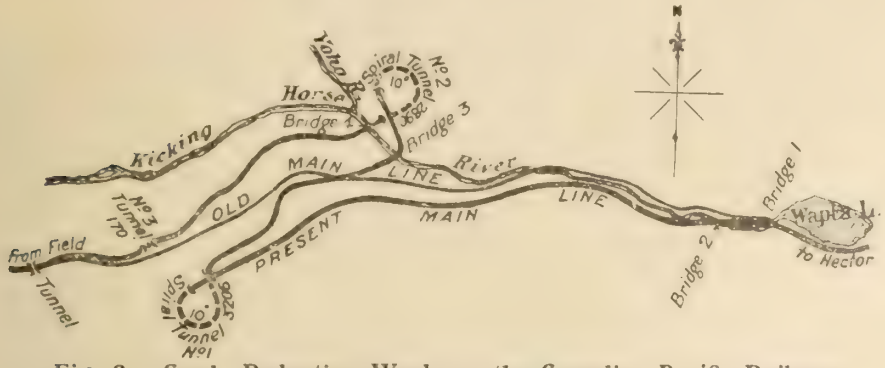


Fig. 2.—Grade Reduction Work on the Canadian Pacific Railway Between Hector and Field, B.C.

Increase in the density and extent of traffic made grade reduction practically a necessity. Reference to Fig. 2 will enable the reader to clearly understand the manner in which this was accomplished. The main line now traverses the valley of the Kicking Horse River between these two stations with an increased length of 8.2 miles and a maximum grade of 2.2 per cent. (compensated).

This development of length was rendered a difficult problem owing to the steep mountain sides on either bank of the river. The only solution lay in tunnelling a loop on each side and in the construction of bridges, as illustrated in the sketch. The driving of these spiral tunnels has been regarded by many engineers as one of the most interesting engineering features of the whole Canadian Pacific Railway improvement. Tunnel No. 1 is 3,206 feet in length, turning an angle under Mount Stephen of about 234 degrees on a 573-foot radius with a grade, as reduced by compensation, of 1.6 per cent., producing a difference of level at the portals of 48 feet. Tunnel No. 2 has a similar radius of curvature through an angle of 232 degrees. It is 2,890 feet long and the grade produces a difference in elevation of about 45 feet at the two portals. Thus the road now traverses the valley by three lines at different elevations. It crosses and recrosses the river by four bridges. The improvement further necessitated the driving of a 170-foot tunnel, this one on a tangent, before connecting with the old line near Field. With the gradients improved to this extent, two engines of the same class as the four previously used can haul 980 tons of freight up the valley.

The spiral tunnels were driven through crystallized limestone of a widely distorted nature. In places, the stratification would vary from nearly horizontal to almost vertical, and in others from normal to almost parallel with the direction of the centre line. The hardness and brittleness of the rock varied every few feet, rendering drilling operations difficult. Water seepage through the rock crevices hampered progress on the down-grade ends of each tunnel, while the high altitude (about 5,000 feet) and severe winter weather added to the adverse con-

Fig. 3.—Portals of Spiral Tunnels Between Hector and Field, B.C.

ditions under which the task was so successfully accomplished.

Roger's Pass Tunnel in the Selkirks.

About 85 miles west of Field, there is at present under construction a double-track tunnel through the Selkirk Range of mountains in British Columbia. The driving of this tunnel is making itself a prominent place in the annals of notable engineering achievements. From portal to portal its centre line will measure 26,400 feet, thereby exceeding by three-fourths of a mile the longest existing tunnel in America. The method by which it is being driven involves the tunnelling of a "pioneer bore" paralleling the centre line of the main tunnel. This feature is new and the interest of tunnel engineers has naturally been aroused the world over. Its adoption arose from the keen desire of the C.P.R. to have the undertaking finished before the close of 1916. There is now no doubt that this aim will be achieved. The world's tunnelling records have been repeatedly broken, and the progress made has certainly vindicated the adoption of the pioneer heading method.

The estimated $12,000,000 expenditure connected with this undertaking is another indication of the efforts that are being made by the Canadian Pacific Railway to eliminate grades and snow troubles that have for years gone hand in hand with Western railway operation. The Selkirk tunnel may be considered an adequate winding-up of vast expenditures and enormous engineering undertakings which the C.P.R. has carried out with a view to perfecting the grade and alignment of its road both east and west of the great wheat fields of the Dominion. The tunnel will bring down the summit elevation of the Selkirk portion of the line from 4,330 feet to 3,791 feet. It will reduce the length of maximum grade from 22.15 miles as at present to 6.61 miles, the maximum grade, 2.2 per cent., remaining the same. It will dispense with about four miles of snow sheds in a length of thirteen miles of main line. It will incidentally reduce the length of the line by about four and a half miles. The total curvature will be considerably reduced and several loops eliminated. Thus, while the maximum train load will remain the same, the operating conditions will be much more favorable in consequence of the lower elevation, the shortening of the grades, and the reduction of expense and delay in the season of snow. In short, one of the most costly sections, from an operating point of view, of the whole system will be entirely eliminated. The large force of pusher engines, snow ploughs and equipment shops, that have necessarily carried on a busy existence at Roger's Pass, in service on both sides of the Selkirk Range, will shortly have to seek ranges anew.

The tunnel, with a bearing under Mount Macdonald of S. 38° 11′ W., is being constructed on a tangent throughout its entire length of five miles. The maximum depth of rock above it is 5,690 feet. For about 1,100 feet at each end the material encountered is clay and boulders, the balance being solid rock, mica, schist and quartzite. Throughout the softer materials the tunnel is being lined with concrete. The finished section will be 24 feet high by 29 feet in width.

The pioneer heading is for the greater part of its length about 45 feet from the centre line of the main tunnel, with its grade, for the most part, 10 feet above the subgrade of the latter, although the western portal is 135 feet and the eastern portal 53 feet above grade. Its headings are 7 feet by 8 feet, and each extends from its portal along the right side of the centre line of the tunnel except in the central portion where the pioneer headings, about a mile apart, are carried over to the centre line and

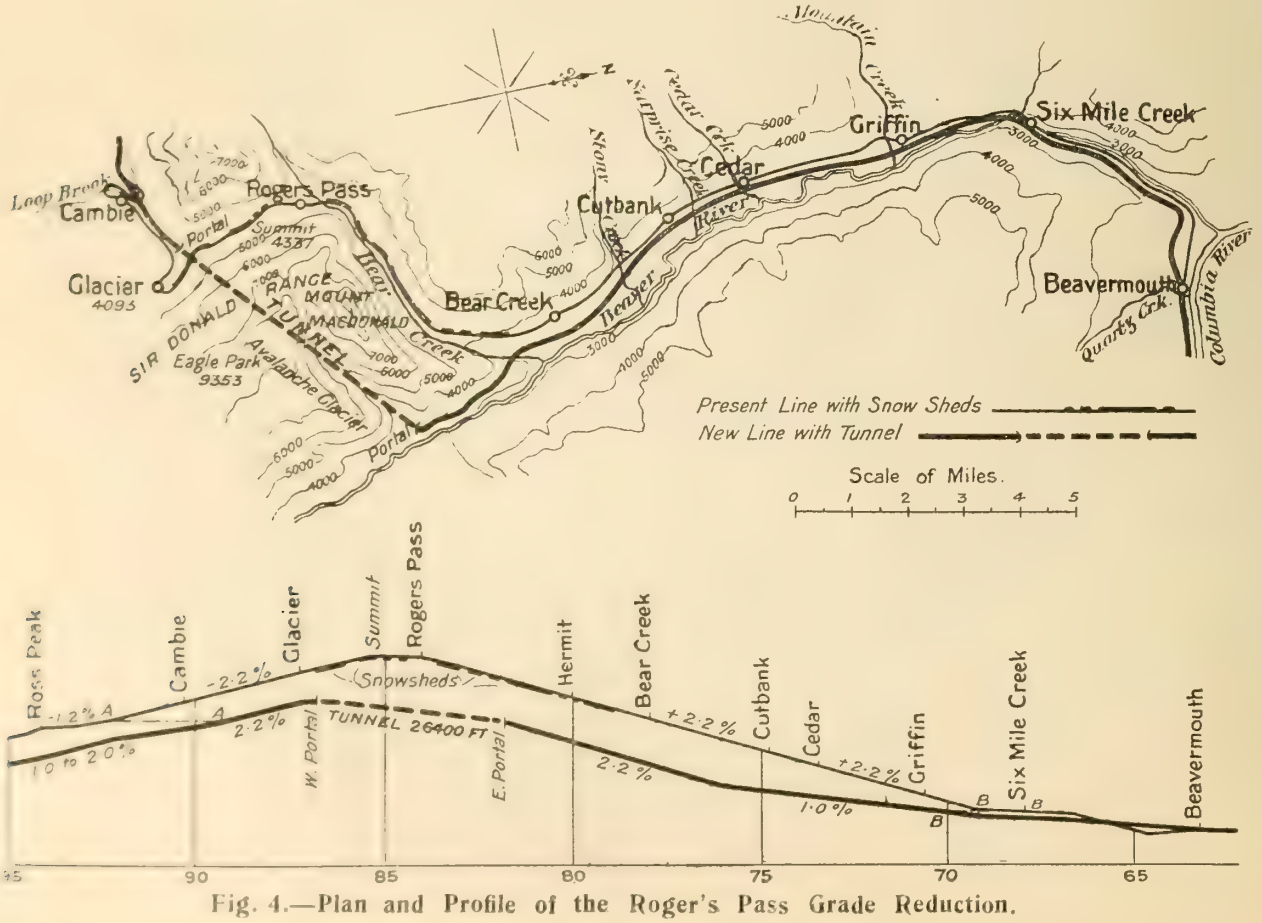


Fig. 4.—Plan and Profile of the Roger's Pass Grade Reduction.

are continued as the centre heading. Cross cuts from these headings to the line of the main tunnel are being made every 1,500 feet or so, and drifts from each cross cut are being driven in both directions. The driving of the main tunnel is thus being accomplished at a large number of headings simultaneously. In addition, the main tunnel work was advanced from each portal. The initial heading is being made as an 8 feet by 11 feet centre heading and the enlargement operations follow closely.

Early in August of this year the pioneer headings were completed to the points where they were carried over to the centre line, and on August 15th they only were 4,920 feet apart. About 2.95 miles of the centre heading has been driven and 1.69 miles of the enlargement completed. Concrete lining of the earth sections will be finished before the end of the year.

Besides necessitating about 18 miles of new track, the tunnel project involved, in its preliminary stages, a 900,000-cu. yd. fill in the centre of the Illecillewaet River valley, extending westward for a distance of 1½ miles. Between this fill and the west portal there is a 300,000-cu. yd. cut, the entrance being at a level of about 80 feet below the ground surface. In the east end there is another approach cut of about 100,000 cu. yd.

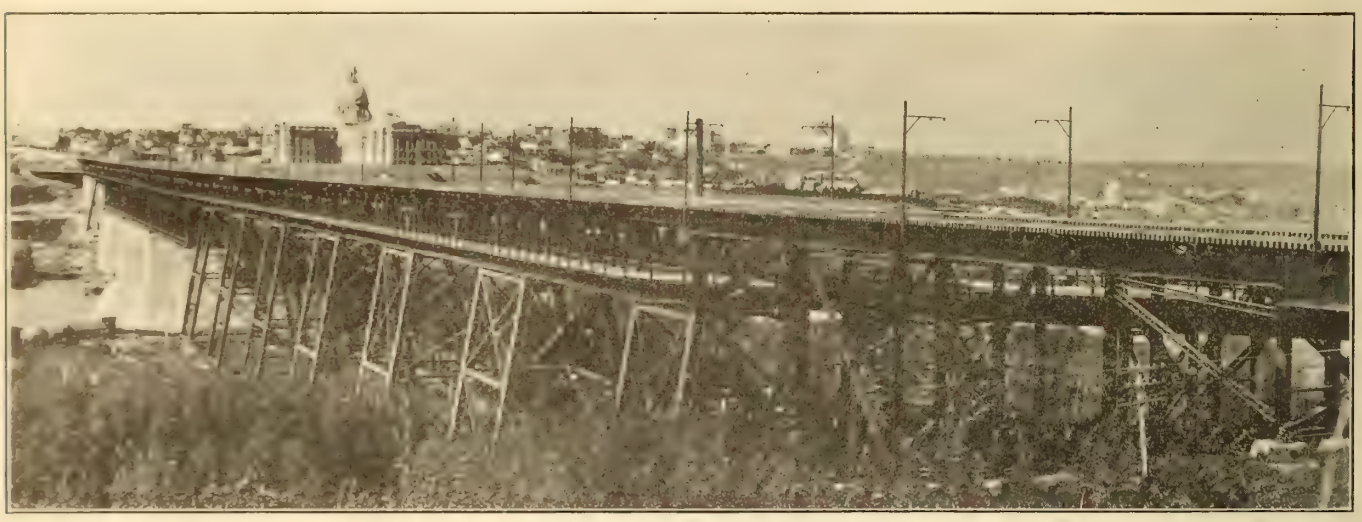
The work, commenced in June, 1914, will probably be completed in September, 1916, several months before the time stipulated. It is being carried out under the direction of Mr. J. G. Sullivan, Chief Engineer of Western Lines for the Canadian Pacific Railway. Mr. H. G. Barber is the engineer-in-charge.

Fig. 5.—East and West Portals of the Roger's Pass Tunnel During Early Stages of the Work.

SOME STEEL RAILWAY VIADUCTS IN WESTERN CANADA

THE CANADIAN PACIFIC RAILWAY VIADUCTS AT LETHBRIDGE, ALTA., EDMONTON, ALTA., AND OUTLOOK, SASK., BRIEFLY DESCRIBED AND ILLUSTRATED.

WHILE the opinions of bridge engineers may differ regarding the features of steel bridge design that bespeak distinctiveness and character, it is improbable that there may be readily called to mind a railway viaduct in Canada with more interesting points relating to its design and construction than the Canadian Pacific Railway viaduct which crosses the Belly River in the western part of the city of Lethbridge, Alta. The structure has received generous comment in the engineering press, not only for its large dimensions, but for little details that illustrate economic judgment in engineering design and dexterity in matters of construction. It stands out so prominently among railway viaducts of the age and is such a striking criterion of the scientific progress surrounding structural steel, that the following brief description of it, in conjunction with the more recently constructed C.P.R. bridges at Edmonton and Outlook, will doubtless atone for another reference to it, even after its six years of use.



The C.P.R. Bridge at Edmonton, Showing Deviation of Highway at Each End.

The Lethbridge Viaduct.

Lethbridge, 759 miles west of Winnipeg, is a divisional point on the Crow's Nest Branch of the Canadian Pacific Railway. It is the centre of an important coal mining district as well as of a large irrigation tract on the eve of springing into greater prominence. The old Crow's Nest line, in its 38½-mile course from Lethbridge Junction to Macleod, had twenty bridges, aggregating nearly three miles of length, a number of them being over 100 ft. high. It had a curve, with no compensation, for every mile and to spare, and was burdened with a 1.2 per cent. grade (63.4 ft. per mile). The rapidly increasing traffic of ten years ago, coupled with the demands of rolling stock, for heavier structures, combined forces with the company's desire for lower grades and better alignment, and resulted in an entirely new line between Lethbridge and Macleod. This, compared with the old, effected a 5.26-mile reduction in length, a saving of 1,735 degrees of curvature (eliminating 37 curves) and a reduction of grade from 1.2 per cent. to 0.4 per cent. The number of bridges was reduced from twenty to two. One is a 1,900-ft. structure over the Old Man River valley, and the other is the world-famous Lethbridge viaduct, 5,327 ft. long with a maximum difference in elevation between river bed and base of rail of 314 ft.

The viaduct consists of 44 plate girder spans 67 ft. 1 in. long, 22 plate girder spans 98 ft. 10 in. long, and a riveted deck lattice truss span 167 ft. long. It is carried on 33 riveted steel towers, rigidly braced. Its general design is clearly illustrated in the accompanying views and elevation diagram. The substructure consists of concrete piles supporting concrete pedestals, the length of the piles under the land piers varying from 12 to 20 ft. The alignment is a tangent throughout. A 3-degree curve exists at the western approach and a 1-degree curve at the eastern approach. There is a grade of 0.4 per cent. rising towards the west for the entire length.

The 33 high bents in the centre of the bridge have four anchor bolts, 2½ inches in diameter in the foot of each column; the remaining bents have two anchor bolts per column. The taper of the towers is 1:6. This, with the girders of the spans spaced at 16-ft. centres, gives ample spread at the base of the towers. The tower spans were made 67 ft. long in order to give longitudinal stiffness to the towers and to reduce the traction stress in the lower legs.

The diagonal bracings, both transverse and longitudinal, are stiff riveted members composed of angles and channels. Latticed and long members, as the illustrations show, are supported at the centre.

The Edmonton Viaduct.

The C.P.R. bridge across the North Saskatchewan River in Edmonton is a double deck structure about 2,687 ft. in length, providing a thoroughfare for vehicles, street cars and pedestrians in addition to railway traffic. The river divides the main part of the city from Edmonton South, which until a year or so ago existed as a separate town, Strathcona. As is characteristic of the rivers of

The River Section of the Lethbridge Viaduct.

the prairie west, the North Saskatchewan is a comparatively shallow stream, but of widely varying flow, traversing at Edmonton a valley upwards of a mile in width, this valley benching abruptly to the prairie level above.

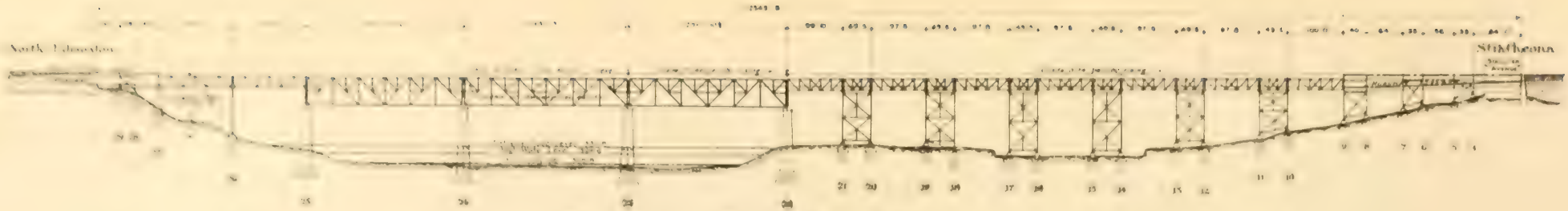
Prior to the erection of the present structure, a low-level swing bridge, used both as a railway and a highway bridge, was the only means of wheel transportation between the two cities.

The new viaduct crosses the river bed by three main double deck truss spans, one 293 ft. 3 inches long, and the other two 291 ft. 10½ inches long, with trusses 50 ft. deep and at 25-ft. centres. The approach on the Edmonton side includes two double deck truss spans, one 129 ft. 9 in. long, and the other 2 ft. longer, with trusses 19 ft. deep and spaced 25 ft. centre to centre. The balance of the approach on the north side consists of three short girder spans, by which the lower deck, for highway and pedestrian traffic, is diverted from under the rail deck, to escape the embankment which meets the latter.

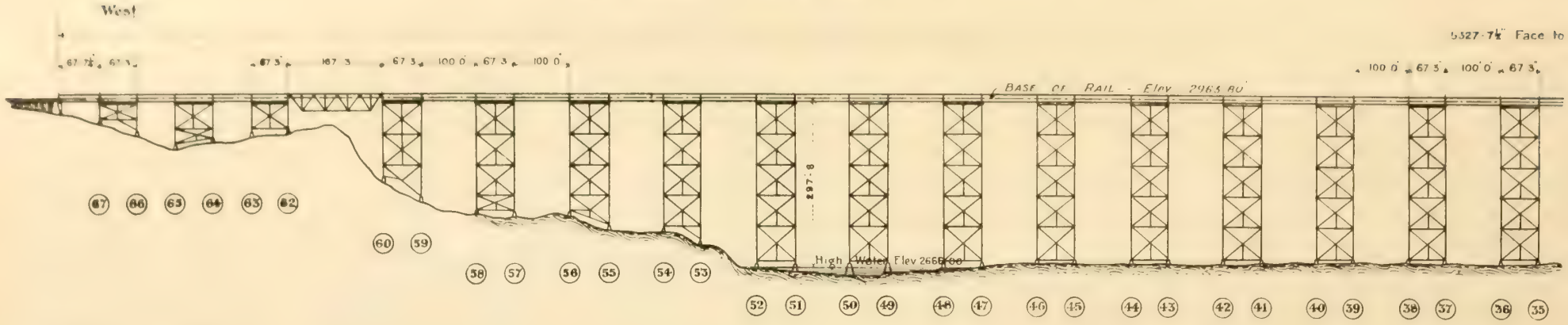
The south approach is a very interesting combination of towers and double deck trusses. The spans on the towers are 49 ft. 5 in. long and those between towers 97 ft. 8 in. long, with the exception of that connecting with the first river pier, it being 99 ft. 10 in. in length. As at the north end, the roadway is run clear of the centre line of the rail deck by girder spans. In this case, however, the roadway rises to the level of the rails some 250 ft. south of the first abutment. The railway leaves the embankment and enters a cut of considerable size before passing under Anthony Street, to the grade of which the street car tracks and roadway rise. Thus, with remarkable provision against traffic interference, the viaduct carries on its upper deck the single-track line of the C.P.R., with street car tracks spaced at 12-ft. 6-in. centres on either side, the necessary width being provided by floor beams extending out over the trusses; while on its lower deck the roadway, a creosoted wood block pavement on reinforced concrete foundation, runs between the trusses and 8-ft. sidewalks are cantilevered on the outside.

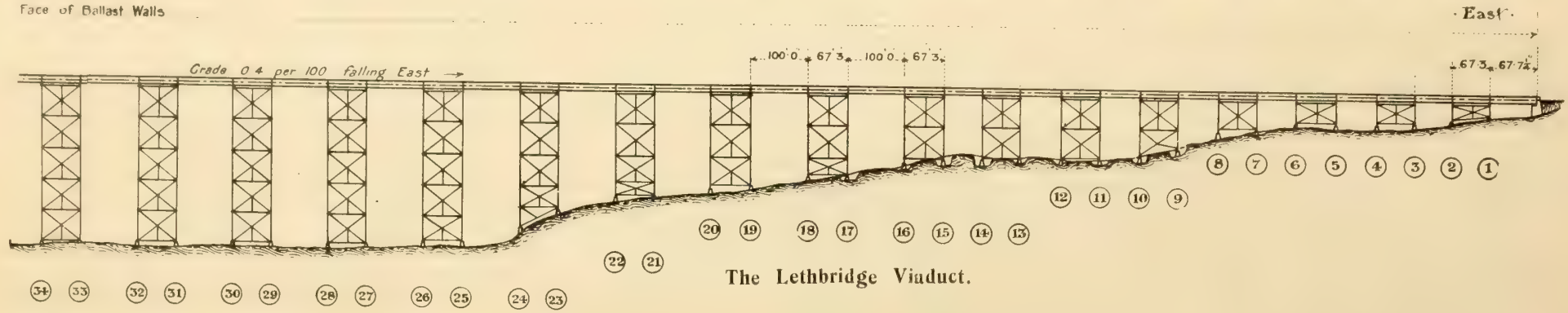
The four piers carrying the three river spans (the rail level of which is over 150 ft. above mean water level) are massive structures carried below the river bed to rock

View of the River Section of the Outlook Bridge. At the Extreme Right is One of the Nine Land Towers.

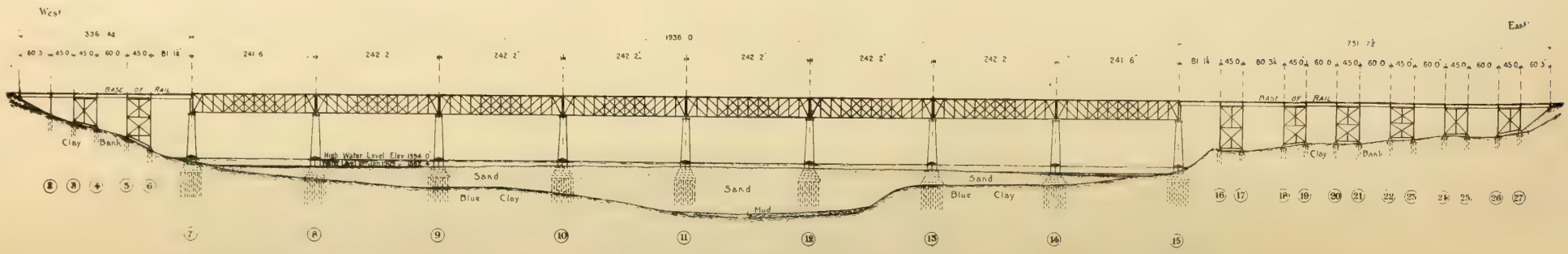


The Edmonton Bridge of the C.P.R.





The Lethbridge Viaduct.



The C.P.R. Bridge at Outlook, Sask.

One of the Concrete Piers of the C.P.R. Bridge at Outlook, Sask., While Under Construction.

foundation. The towers rest on concrete pedestals supported by concrete piles.

The Bridge at Outlook, Sask.

The line of the Canadian Pacific Railway running northwest from Moose Jaw, Sask., crosses the South Saskatchewan River near Outlook by a high-level bridge built in 1911 and 1912. This is another handsome steel structure supported on massive piers of concrete, the approaches being in each case a steel trestle supported upon concrete pedestals.

The main spans above the river consist of eight 240-ft. long deck double intersection truss spans weighing approximately 4,052,000 pounds. The trusses are at 16-ft. centres. The steel trestle approaches consist of three 80-ft. and seven 60-ft. open spans and nine 45-ft. tower spans. The girders of these approaches are at 10-ft. centres and the legs of the towers have a batter of 1 in 6. Both trestle approaches rest on pedestals supported by concrete piles. Common to both approaches is what is generally known as "stiff" construction with riveted connections, there being no rods or pins in the work.

The river piers are supported on wooden piles driven to refusal in the sand and blue clay formation underneath. The substructure work was carried out under extreme flood and temperature difficulties. Several of the tall piers had to be constructed inside of specially built housing under artificial heat.

The total length of the bridge from face to face of ballast walls is 3,004 ft. and the height above river bottom in the deepest place is approximately 150 ft. The total weight of steel used is in the neighborhood of 6,000,000 pounds, while the total yardage of concrete in the piers and pedestals amounts to about 33,500 cubic yards.

The deck of the bridge consists of the usual Canadian Pacific Railway standard ties and guard rails, and the river spans have their top chords projecting about 16 ins. above the base of rail, forming an additional safeguard should a train become derailed on the bridge.

A general elevation diagram of the structure is shown herewith. The massiveness of the concrete piers is evidenced by the illustration of one of them, and the extremely interesting appearance of the bridge in general, notwithstanding the difficulties of climate and geology which handicapped its construction to a certain extent, is shown by the accompanying views.

SOME EASTERN BRIDGES, CANADIAN PACIFIC RAILWAY

EXAMPLES OF UNUSUAL AND WIDELY DIFFERING DESIGN, AS FOUND AT SAULT STE. MARIE, AND ACROSS THE ST. LAWRENCE RIVER AND LACHINE CANAL, NEAR MONTREAL.

THE Lethbridge, Edmonton and Outlook bridges of the Canadian Pacific Railway distinctively exemplify one type of bridge construction in its most modern stage. These structures present to the traveller a rare conception of size and proportions of design. At the same time, unless his is a practised eye in structural design, dissimilar features may be overlooked and bridge work in general consigned to a narrow category. That enormity in railway bridges does not bide with a single type is better illustrated on a number of the company's lines east of Winnipeg. Among the most interesting are the bascule bridge which connects Sault Ste. Marie on the Ontario side with the Michigan city of the same name; the double-track swing bridge over the Lachine Canal on the Farnham subdivision of the C.P.R., and the St. Lawrence River bridge near Lachine, on the same subdivision. A brief description of each of these is given below.

The C.P.R. Bascule Bridge at Sault Ste. Marie with One River Arm Fully Opened.

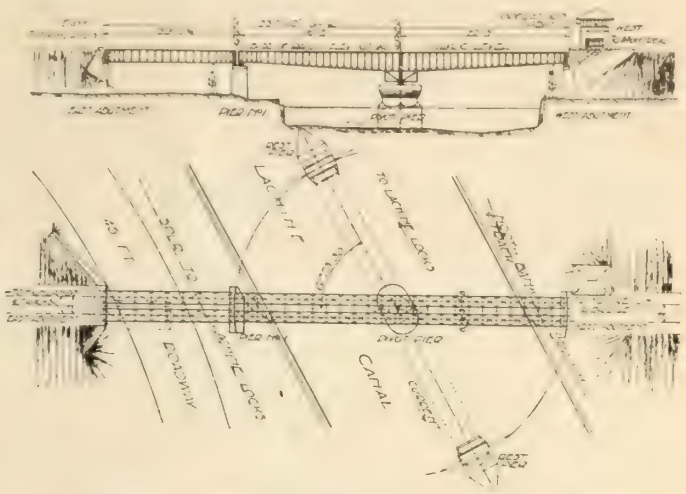
The Sault Ste. Marie Bascule Bridge.

The single-track bascule bridge over the United States ship canal at Sault Ste. Marie has a span of 336 ft. c. to c. of channel piers. It provides a single unobstructed channel wider than that given by the longest existing movable bridge; besides which it was constructed in record time. It possesses a number of features peculiarly its own. Each leaf consists of a 168-ft. arm and a 45-ft. tower, being accurately balanced by counterweights containing each about 550 cubic yards of concrete and weighing over 1,000 tons. Instead of acting as a cantilever for live load, as is ordinarily the case with double leaf bascule bridges, the two arms are so locked

together in the centre, when the bridge is closed, that the two halves of the trusses act as a single simple span from pier to pier. The locking of the trusses in the centre is automatic and does not involve moving parts of any kind. The south leaf and its steel tower rest as a unit on rollers allowing a 6-inch transverse movement, which involves the entire tower and attached leaf, and is effected by hydraulic cylinders. Rapid and perfect alignment of the two leaves at the point of closing is a feature that bespeaks some very accurate detailing, both in the matter of design and construction.

The Sault Ste. Marie Bridge in the Process of Being Opened to Canal Traffic.

Both leaves may be fully opened to the vessels of larger dimensions and deeper draught which use the centre of the channel; or one may be opened to permit passage of smaller vessels. Owing, however, to the ease of handling both leaves, accomplished by the electrically operated machinery, it is customary for the tower man to open both when canal traffic demands.



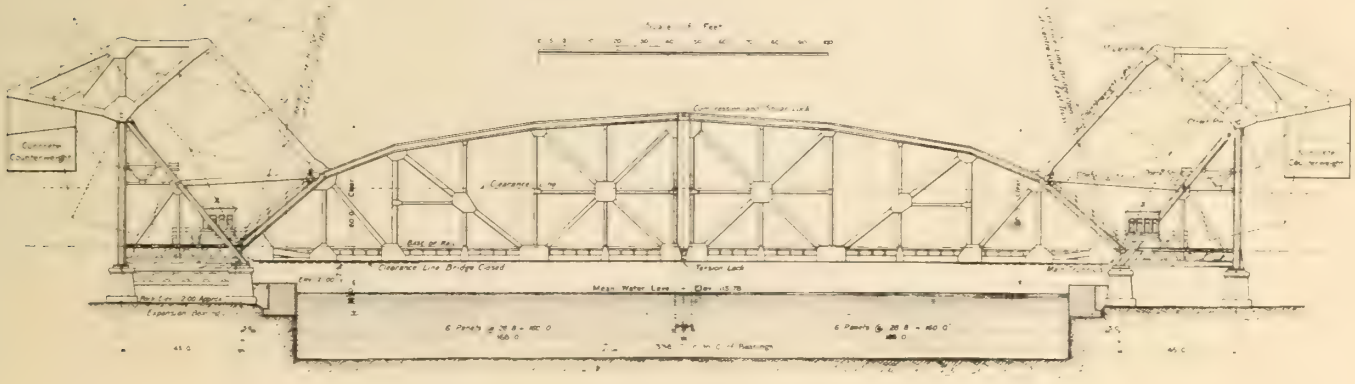
Alignment and Dimensions of the Lachine Canal Swing Bridge.

structure in being the longest of its kind in existence, and it had similarly associated with its construction some remarkable speed. The improvement was decided upon by the company last autumn. Substructure work began on December 1st, 1914. The bridge seats were ready to receive the girders in ten weeks' time, and in another ten weeks trains were passing over the completed structure.

The swing span is 239 feet 7 inches long, with a girder depth at the centre pivot of 13 feet 6½ inches, diminishing to 8 feet ½ inch at the ends, measured from back to back of flange angles. The span weighs about 615 tons, and is operated by 30-h.p. duplex motors, the difference in time between closed alignment for railway service and open alignment for the passage of canal traffic being a period of only 70 seconds. The regulation of traffic on both railway and canal in the vicinity of the bridge is effected by very complete power-operated signal and electric track circuit interlocking systems. All operation is looked after from the operating house on the north bank of the canal. The approach span on the opposite bank, shown in the illustration, is 90 feet long.

The structure replaces a single-track bridge, built in 1887, the new double-track span having been de-

Trunnion Bascule Bridge of the C.P.R. at Sault Ste. Marie.



The bridge was put into service in September, 1914. The accompanying illustrations indicate its unique design and the manner of its operation.

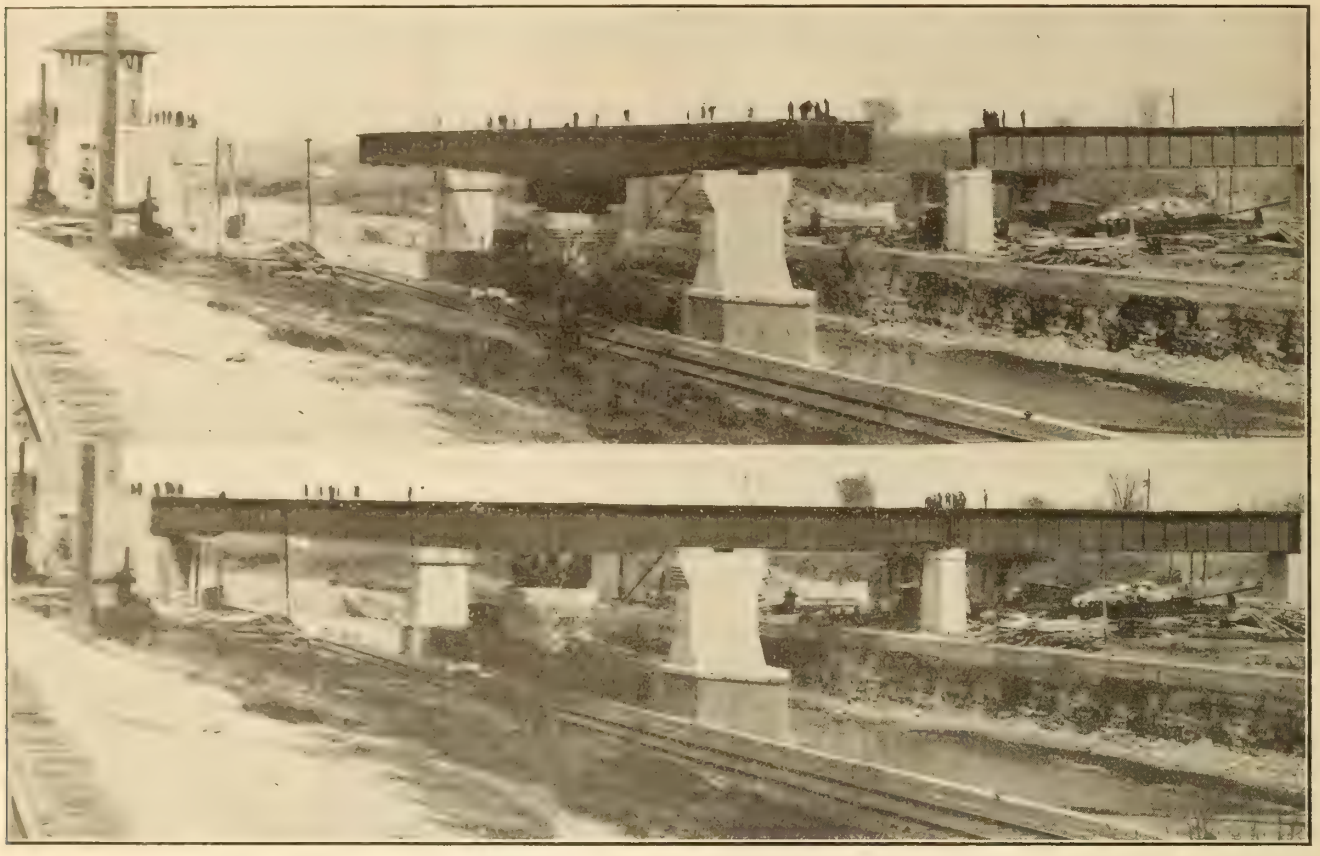
Lachine Canal Swing Bridge.

Another structure depicting the advanced stage of the design, operation and control of large bridges of the movable type, is the electrically operated double-track swing span over the Lachine Canal, put into operation last April as a part of the system of double tracking between Montreal and Brigham Junction. This plate girder swing span shares distinction with the Sault Ste. Marie

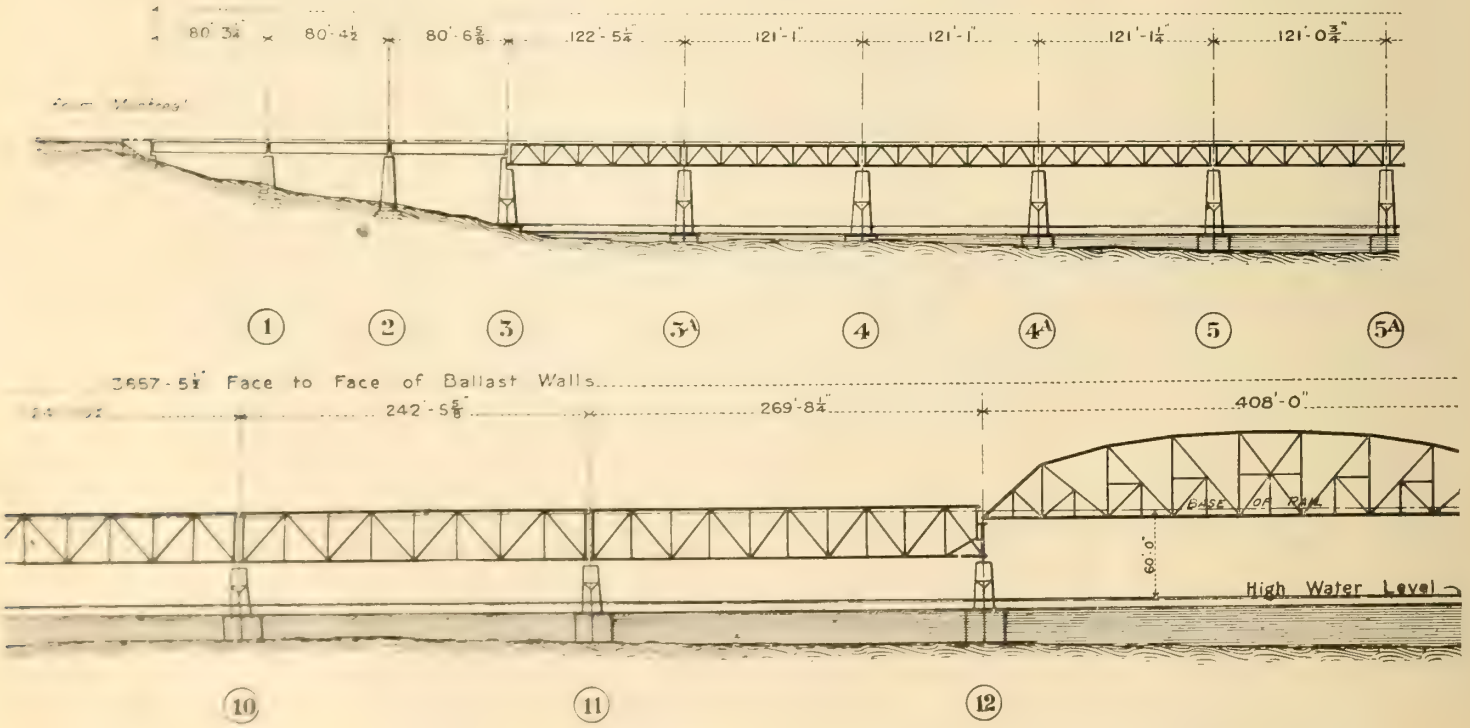
signed in such a manner by the company's bridge department as to utilize the old pivot pier, without decreasing in any respect the width of waterway for canal traffic.

The St. Lawrence River Bridge.

When traffic on the Farnham subdivision of the Canadian Pacific Railway had increased both in volume and density to such an extent as to demand double tracking between Montreal and Brigham Junction, the reconstruction of the St. Lawrence River bridge between Highlands and Caughnawaga, about 8 miles from the Montreal terminal, presented a number of engineering problems of unusual nature. The old bridge, built in 1886, was a single-track structure, and was in its day considered a



The Lachine Canal Swing Span in Its Open and Closed Positions.



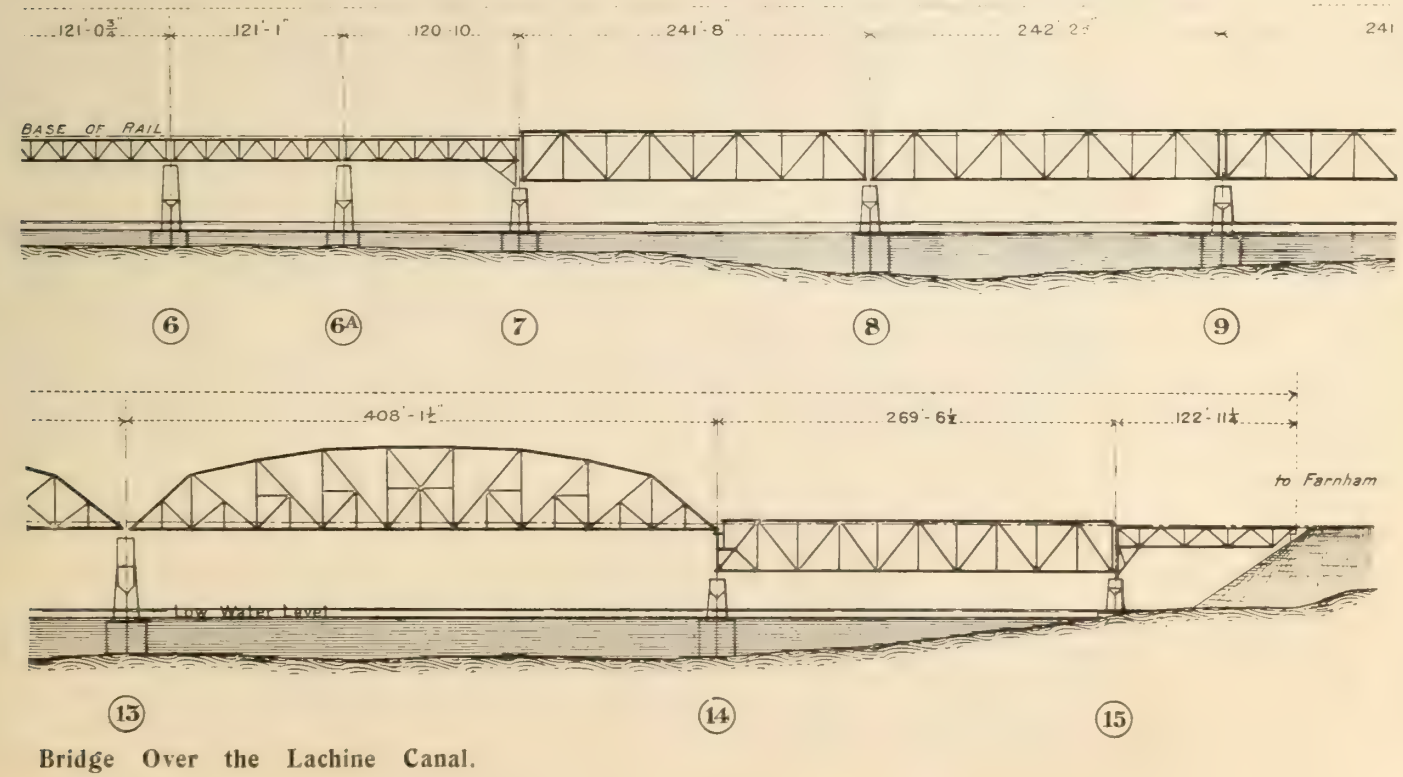
The St. Lawrence River

fine example of advanced bridge design. It had three 80-foot deck girders, one 120-foot deck truss span, eight 240-foot deck trusses, two 270-foot flanking spans, and two channel spans each 408 ft. long. Reconstruction was to be carried out without interruption to traffic. The river piers were to be enlarged, some of which were in a current of about 8 miles an hour, and in water 30 ft. deep, the superstructure in the steamer channels being approximately 70 ft. above water level.

The Channel Spans of the St. Lawrence River Bridge.

The old single-track structure was replaced by two parallel single-track bridges designed for much heavier loading than previously used. One of the bridges coincides in alignment with the old, while the other is down stream 27 feet c. to c., tapering to 16 feet 4 inches c. to c. where the tracks approach each other at the north abutment. The down-stream bridge rests on extensions of the old piers, although four new piers were built dividing the old 240-foot spans into eight 120-foot spans. The old piers and abutments involved 12,400 cubic yards of masonry, to which were added some 13,300 cubic yards for the new bridge. The 4,100 tons of steel work in the old structure were replaced by 14,231 tons in the new. It is interesting to note that in the latter there are 3½ million rivets.

The adoption of two single-track bridges instead of a double-track structure, combined with the use of crossovers as construction work proceeded, obviated interruption to traffic. Some of the most interesting details of



Bridge Over the Lachine Canal.

bridge construction handicapped by traffic conditions are connected therewith. The extensive cofferdamming in conjunction with pier work and the pneumatic caissons employed in enlarging the deep-water piers, are also well known to engineers.

The finished bridge, as illustrated herewith, consists of the following spans, viewed from the north end: Three 80-ft. deck plate girders; eight 120-ft. deck Warren truss spans (which were the four 240-ft. spans in the old bridge); four 240-ft. deck Warren truss spans; one 270-ft. deck Warren truss; two 480-ft. through Pratt curved-chord sub-panelled trusses; one 270-ft. deck Warren truss, and one 120-ft. deck Warren truss.

One Channel Span of the St. Lawrence River Bridge Moving Into Place.

LOCOMOTIVE AND CAR SHOPS OF THE CANADIAN PACIFIC RAILWAY

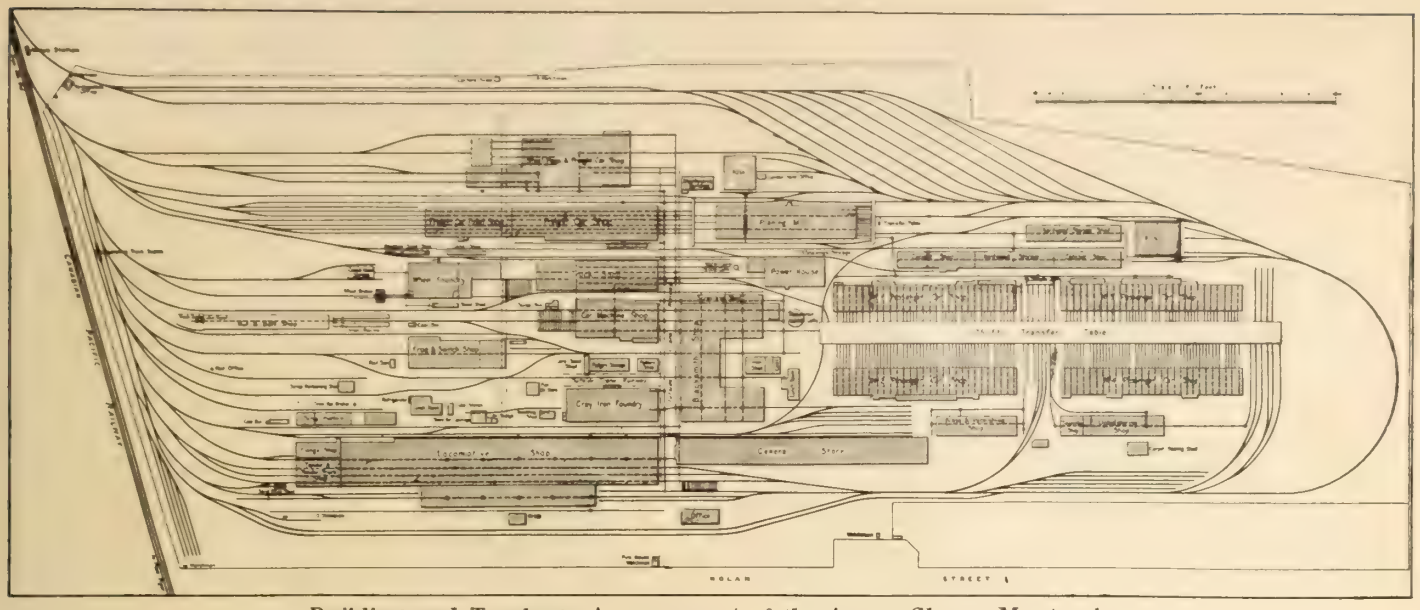
DESCRIPTIONS OF THE ANGUS SHOPS, MONTREAL, AND THE OGDEN SHOPS, NEAR CALGARY, FOR THE UPKEEP OF ROLLING STOCK ON THE EASTERN AND WESTERN LINES RESPECTIVELY.

IN a railway system of nearly 15,000 miles, earning annually over $10,000 per mile, the upkeep of rolling stock is an item upon which much depends. Safety, despatch and reliability of service figure largely in the eye of the travelling public, and, while many are apt to stop after a question of roadbed or upholstering, the more experienced traveller fully understands the vital importance of the many mechanical details surrounding locomotives and cars and their efficient operation. During the recent tremendous strides in track laying throughout Canada—strides that have set the world wondering as to her knowledge of the obligations they entail, strides, in fact, that have forced many a prominent railway authority to believe that track laying in Canada has been immensely over-done of late—one has lost sight of the item of wear and tear to rolling stock on old established lines, particularly under the heavy traffic that the road under consideration has met, and met with a preparedness that warrants some brief explanation.

It is interesting to know that this term "rolling stock" includes in the case of the C.P.R. some 2,255 locomotives ranging up to the Mallet Compound type, over 2,700 passenger cars and upwards of 87,500 freight cars. The orders of the company in 1912 amounted to 493 locomotives of the superheater type alone, nearly 500 passenger cars and 28,400 freight cars. It is evident that the question, not only of construction, but of proper maintenance and repair, is a very important one for the C.P.R.

The C.P.R. Shops at Angus, Quebec.

These requirements are looked after for the most part in two large shops, *viz.*, the Angus shops, near Montreal,



Building and Trackage Arrangement of the Angus Shops, Montreal.

for the rolling stock on the eastern lines, and the Ogden shops, near Calgary, Alberta, for similar service on western lines. The former shops have been in use for ten years, but were enlarged in 1913 to include the construction of steel passenger and freight cars. The Ogden shops were put into operation in the spring of 1913.

The Angus Shops.

The city of Montreal has grown to now practically include within its boundaries the Angus shops in its eastern section. These are on a plateau 175 ft. above the St. Lawrence River, and cover an area of about 200 acres. It is impossible to find on any line of railway a more desirable site, and the same is practically true in the matter of building and plant arrangement. For the purposes of brief description, the shops may be dealt with in three divisions: shops devoted exclusively to car works, shops for locomotive construction and repairs, and shops common to both of these departments. It is to be borne in mind, as is evident from an inspection of the arrangement, that a primary bearing on the original design was the question of economical and direct handling of material during the processes of manufacture. The layout is virtually a combination of transverse systems, as indicated in the accompanying plan. When first constructed, each building was arranged to provide for future enlargement and for the incorporation of additional buildings when required. The judgment of various extensive preliminary investigations into details of arrangement have been severely tested and vindicated during the past few

A Section of the Locomotive Erecting Shop at Angus, Quebec.

years, particularly upon the subsequent erection of the steel-car shops.

The department devoted to car work comprises separate shops for passenger cars, freight cars, and trucks, in addition to planing mill, cabinet shop, machine shop, wheel foundry and dry kilns. The locomotive work is mainly concentrated in the large locomotive and erecting shops, while the foundry, pattern shop, and blacksmith shop serve both these departments.

The buildings are arranged along a transverse avenue 80 ft. wide, over which a 10-ton overhead travelling electric crane operates through a distance of about 1,000 ft.

The locomotive shop is of the longitudinal type, with three bays each 1,165 ft. long, of which 300 ft. is devoted to tank work. The erecting bay is 80 ft. wide, the machine shop bay 50 ft. wide, and the third bay 25 ft. wide. In the erecting bay the locomotives are handled by two 60-ton electric travelling cranes, each with a 10-ton auxiliary. There is a 20-ton crane in the boiler shop, while the machine shop is equipped with one 15-ton and one 10-ton crane over its 50-ft. span.

The old freight-car shop has a capacity of 25 to 30 cars per day. It has four tracks for erection purposes, each 540 ft. long, besides intermediate supply tracks. Six travelling cranes fitted with air hoists are in operation over its width of 107 ft.

The old passenger-car shops are 100 ft. wide and 672 ft. long. There are four of them, each having 28 tracks spaced at 24-ft. centres. They are served by a transfer table over which operates an electric crane with 75-ft. span.

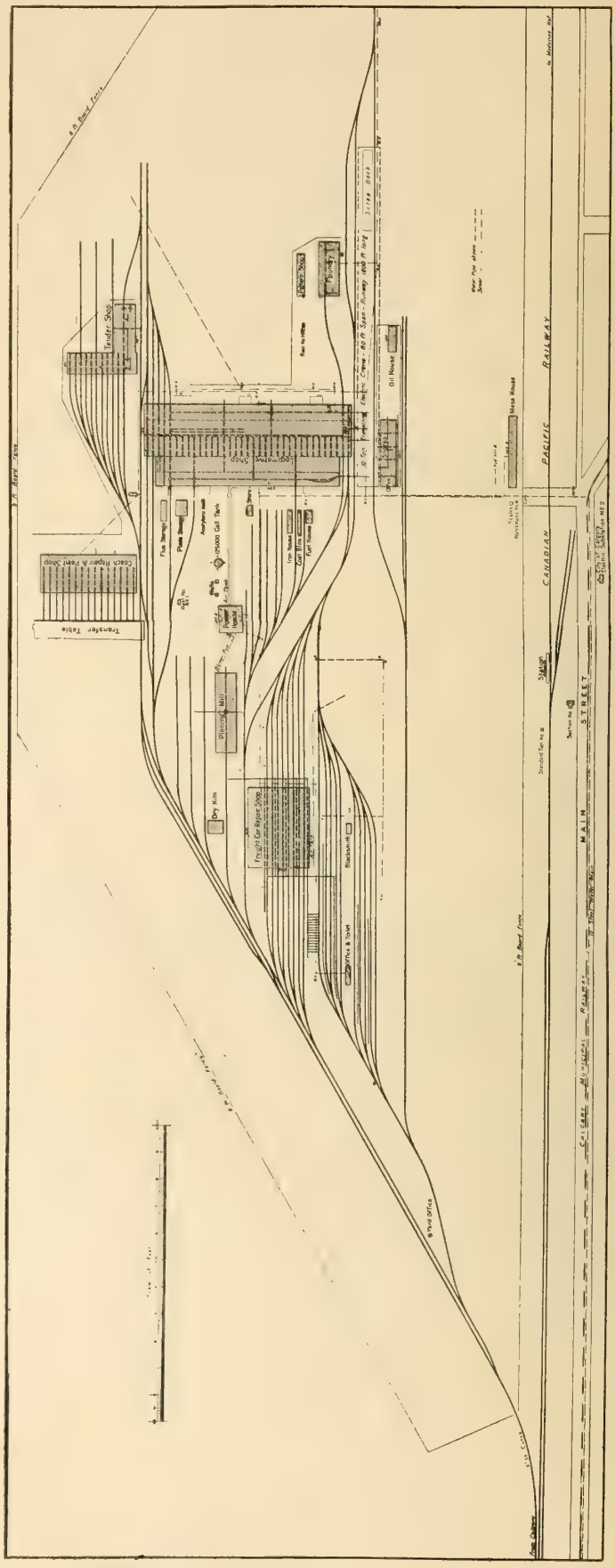
Power for mechanical and lighting purposes is generated in a central plant, equipped with seven 415-h.p. boilers, working under 150 lb. pressure, one 150° superheat boiler, and one boiler for testing up to 300 lbs. The plant includes three 750-h.p., cross compound, non-condensing engines, connected to 500-k.w. a.c. generators, at 150 r.p.m. These units provide all light and power excepting that necessary for variable speed tools and for cranes. A special d.c. generator, driven by a 300-h.p. simple engine at 180 r.p.m., supplies this. The plant is fully equipped with motors of varying capacities and speeds.

The new shops, added in 1913, and used exclusively for the construction of steel passenger and freight cars, have a capacity for 10 of the former per month and 8 of the latter per day. The freight-car section added over 41,500 sq. ft. and the passenger-car section over 47,000 sq. ft. to the total floor area of the plant. The truck department of the old shop supplies the trucks for both the new additions, apart from which the latter are practically complete in themselves.

The steel shop proper consists of two 100-ft. bays running parallel and one 72-ft. bay, 405 ft. long, at right angles to them. The passenger shop erecting section is composed of four 27½-ft. bays, 202½ ft. long, at right angles to the 100-ft. bays and parallel to the freight section. The crane service includes a 10-ton travelling crane of 96 ft. 3 in. span, on a 309-ft. runway covering the material section of the shop. There is a 10-ton crane of like span in each of the bays. All these cranes provide a headroom of 27 ft.

In the erecting section of the freight shop there is a 10-ton crane of 67½ ft. span and 35½ ft. headroom. In the passenger shops 4 cranes, each of 2-ton capacity, 24 ft. 10 in. span, and 20 ft. headroom are used for handling light material.

The new building is of steel with brick walls, the design specially providing for a large area of light, the window space occupying about 30 per cent. of the total wall space.



The C.P.R. Shops at Ogden, Alberta.

In each shop there is a very systematic routing of material and of operations, from the point where the trucks are brought in until the finished cars are reported for service. There is a decided uniformity in both shops in the arrangement of machinery, and in the method of handling supplies.

There are many items of note to engineers regarding structural features, water supply, sewerage system, fire protection, etc., as well as engine machinery and equipment.

The Ogden Shops.

This system of shops is situated on a stretch of open prairie about 4½ miles from Calgary, being distant from its eastern complement by some 2,250 miles. The Ogden shops consist of a main locomotive shop, including boiler, machine, blacksmith and erecting shops, repair shops for both passenger and freight cars, and the necessary pattern shops, planing mill, foundry, tender and wheel shops.

The locomotive erecting shop is of the transverse lift-over type, 778 ft. long and 75 ft. wide. It contains 35 bays at 25-ft. centres. Two electric cranes, one of them of 120 tons capacity, and equipped with 50-ton trolleys, operate over the entire shop. Another electric crane operates to and fro between the erecting shop and the blacksmith and machine shops which parallel it on either side. There are two machine shops, each 778 ft. long and 60 ft. 9 in. wide. One of these contains the heavier machine tools, while in the other is located the lighter machines. Each is furnished with a high-speed crane. The blacksmith shop is on the opposite side of the erecting shop and consists of two bays, each 332 ft. long, with widths of 60 ft. 9 in. and 50 ft. respectively. Jib cranes handle the material here from the steam hammers, forgings, etc. Alongside this shop are the furnaces, bolt headers and other blacksmith shop machinery. The boiler shop is 352 ft. long, being of the same width as the blacksmith shop and in line with it adjacent to the erecting shop. It is equipped with a 40-ton travelling crane, and several 20-ton trolleys. It has several bays devoted to flue shop and boiler shop tools attended by trolley and jib cranes.

These departments are all housed in a structural steel frame building on concrete foundations. The problems of ventilation and natural lighting were well looked after in the design, with roof monitors, skylights, and swinging sash.

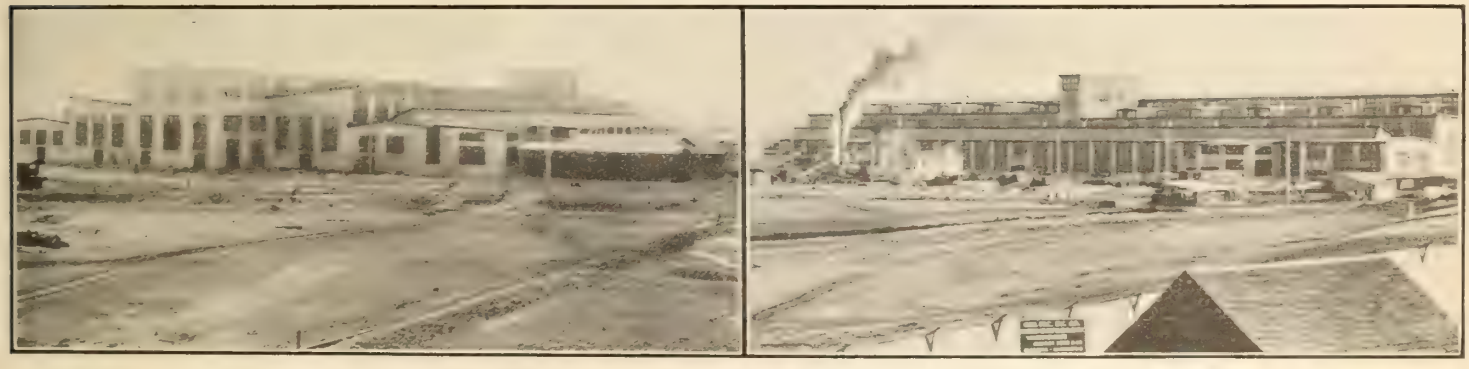
The tender and wheel shop is also of structural steel frame, but with steel roof trusses. It is an L-shaped structure, 80 ft. wide, with lengths of 263 ft. and 180 ft. respectively.

It is equipped with longitudinal tracks of 20-ft. centres, and with a 20-ton high-speed crane. Here repairs are made to locomotive tenders, steam shovels, and maintenance-of-way equipment. The wheel section is provided with steel-tire wheel lathes and other wheel tools.

The pattern shop is 162 ft. long by 31 ft. wide, similarly constructed of steel with concrete foundation. The grey iron foundry building is 203 ft. long by 80 ft. wide, constructed with two bays. The coach repair shop, 362 ft. long and 146 ft. wide, is furnished with 15 tracks at 24-ft. centres. It is of hollow tile construction on concrete foundation. The freight repair shop, 303 ft. by 231 ft., has eight repair tracks arranged in pairs with service tracks between. The blacksmith shop, forges, etc., are situated along one side, in separate rooms.

There is, in addition, a 303 x 80-ft. wood planing mill, a 350 x 90-ft. material platform, a 252 x 60-ft. office building, a boiler house with water tube boilers aggregating 21,000 h.p. in units of 350 h.p. each, set in three batteries of two each. There is a yard crane runway 1,260 ft. long, a coach shop transfer cable, of 150 tons capacity, and a complete set of buildings for the working force.

Ground was broken at Ogden on April 1st, 1912, and on March 17th, 1913, the locomotive shop was in full operation.



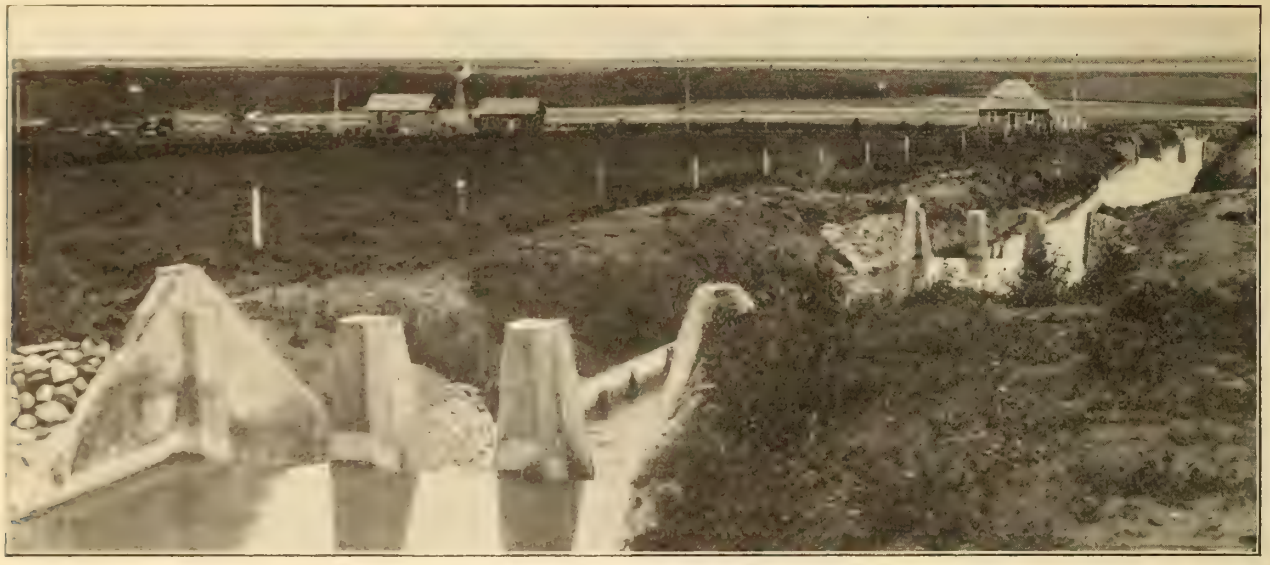
Locomotive, Erecting and Machine Shop Section of the C.P.R. Shops at Ogden, Alberta.

THE CANADIAN PACIFIC RAILWAY IRRIGATION SYSTEM IN ALBERTA

THE SIGNIFICANCE OF THE PROJECT—ITS WESTERN, CENTRAL AND EASTERN SECTIONS—THE HORSE SHOE BEND DAM AND THE BROOKS AQUEDUCT.

THE revenue-producing value of any agricultural country depends primarily on the intensity of its farming industry, the fertility of its soil and the certainty of proper maturity of its crops. The Bow River Irrigation Block in Alberta is a striking example of how these prerequisites may be interrelated. With millions of acres of fertile land in its possession, the Canadian Pacific Railway removed the liability of drought and beckoned the farmer. The result—a revenue-producing agricultural country. Millions were invested for an assured perpetuity in the form of traffic receipts.

A series of dry years in Alberta a quarter century ago developed the question of artificial application of water to the doubtful crops. This was not new in the enterprises of civilization; the Egyptians, Arabians, Assyrians, Romans, and the Chinese found, as we find to-day, that it paid. There are over 100 million acres of irrigated land in the world, representing an investment of well over one billion dollars, and annually producing crops valued at considerably over that amount.



Drops in One of the Canals in the Western Section.

The Bow River Irrigation Block, owned by the C.P.R., has a length of about 140 miles eastward from Calgary with an average width of about 40 miles. It embraces an open prairie plateau 2,300 ft. above sea level at its eastern extremity, rising an additional 1,100 ft. toward its western boundary. It is divided by natural topography into three sections of about 1,000,000 acres each, designated the Western, Central and Eastern Sections.

The Western Section.

The irrigation works of this section have been in operation for several years. The section comprises 969,852.26 acres, of which nearly 300,000 acres have been brought under irrigation. The water is diverted from the Bow River at a point about two miles below Calgary. The head works were first constructed of timber, including wooden gates of the straight lift type, operated by rack and pinion, and about 1,750 ft. of pile and timber wall along the river bank. Last year permanent works were installed, which were placed in service December 17th, 1914.

They consist of a concrete intake to the main canal in East Calgary; and, immediately below and at right angles to it, stretching across the Bow River, a weir consisting of a bear trap dam with overhead bridge, 152 ft. long, a stop-log section 555 ft. long and earthen breaching 125 ft. long. The stop logs are handled by a traveling electric winch operating on tracks above them, while the bear trap is worked hydraulically. The head gate sluices may be worked by separate motors, not yet installed.

The water is carried south and east through a main canal 17 miles in length, which in part is 60 ft. wide at the bottom, 120 ft. wide at the water line and designed to carry water to a depth of 10 ft. The larger portion of this canal is 44 ft. bed width and 84 ft. wide at the water line. It delivers to a reservoir for which a natural depression has been utilized and where, by the erection of a large earth dam, a body of water 3 miles long, half a mile wide and 40 ft. deep, has been created. Just before reaching this reservoir the canal makes a vertical drop of 10 ft., necessitating a velocity-retarding water cushion.

From this reservoir the water is taken out in three secondary canals, A, B and C, and carried to different districts. These canals have a combined length of 250 miles. Canal A carries 8 ft. of water, with 18 ft. bed width; Canal B, 6 ft. of water with 28 ft. bed width; Canal C, 6 ft. of water, bed width 40 ft.; these dimensions

relating to their westerly ends. From these canals the water is distributed in each irrigation district through a comprehensive system of ditches.

Altogether the western section comprises 17 miles of main canal, 254 miles of secondary canals and 1,329 miles of distributing ditches, not including several hundred miles of smaller ditches constructed by the farmers themselves. There are head gates, spillways, flumes, drops, bridges, syphons, weirs, etc., numbering in thousands, in the construction of which some ten million feet of timber and ten thousand cubic yards of reinforced concrete were used, and ten million cubic yards of material excavated.

The New Intake on the Bow River Near Calgary, Western Section.

The Central Section.

This section comprises 870,481 acres, of which it is estimated about 200,000 can be irrigated. The original intention was that this section be served by an enlargement of a portion of the trunk system of the western section, but this has, as yet, not been developed.

The Eastern Section.

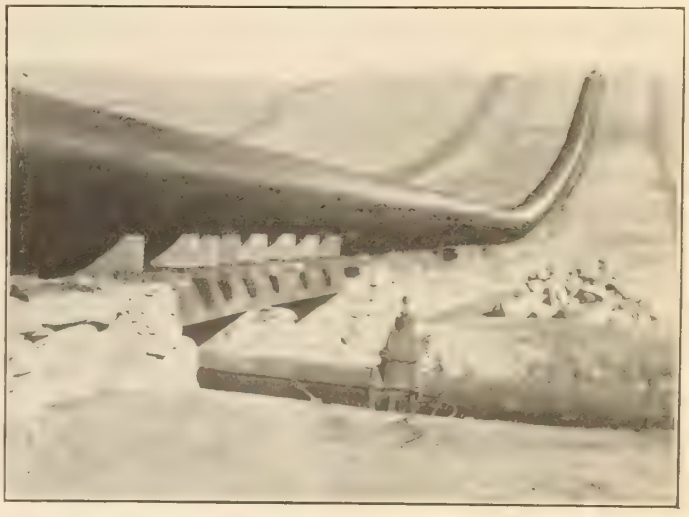
This section is composed of 1,245,732 acres, of which about 440,000 acres are rendered irrigable. Most of this land is of a gently rolling nature and susceptible to good drainage. The system is an entirely independent one from those just described, having an intake of its own located about three miles southwest of Bassano, a point on the main line of the C.P.R., 83 miles east of Calgary. Here it takes advantage of a low pass through the rim of the Bow valley, locally known as the Horse Shoe Bend, taking water from the river by an intake at that point. The dam, which was built a few years ago and which, known as the Bassano or the Horse Shoe Bend dam, is one of the outstanding engineering features of the whole development, will be briefly described in a subsequent paragraph.

At a point about five miles from the intake an earth dam 1,280 ft. in length, 35 ft. maximum height and containing 80,000 cubic yards, was built across the valley, forming a tail pool into which the main canal discharges and from which two branch canals head. The north branch, the smaller of the two, serves the country lying north and east of Mat-zi-win Creek. At the outset the canal has a bed width of about 30 ft. and carries about 6½ ft. of water. After crossing the railway line, it follows the west flank of Crawling Valley to a point about eight miles north of its intake, where it crosses the valley by a flume and runs northerly. It has numerous branches naturally becoming smaller as the distributaries are thrown off, and finally tailing out at the Red Deer River.

The east branch, where it heads out from the tail pool of the main canal, is about 70 ft. wide and carries 9.3 ft. of water. Its general course is southeast, and it serves the balance of the section. Its first branch is near Lathom, crossing the railway and watering a large area between the two forks of Mat-zi-win Creek. It is known as the Spring Hill Canal, and is about 35 ft. bed width, carrying 7 ft. of water.

The east branch, continuing southeasterly, reaches a height of land at the head of Antelope Creek where it forks. One branch is the Bow Slope Canal, 17 ft. wide, 5 ft. water depth and serves all the land on the Bow Slope. At Cassils, two smaller canals are taken off and just south of Brooks the east branch discharges part of its water into Lake Newell reservoir, which was formed in a depression in the Little Rolling Hills by the construction of a number of earth dams, the largest of which is about 2,000 ft. long and 30 ft. in height. This reservoir is nine miles long and four miles in width, with a storage capacity of 185,000 acre-feet. The balance of the water in the east branch goes down the east flank of Rolling Hills on a high grade line in a canal 20 ft. wide and carrying 5½ ft. of water.

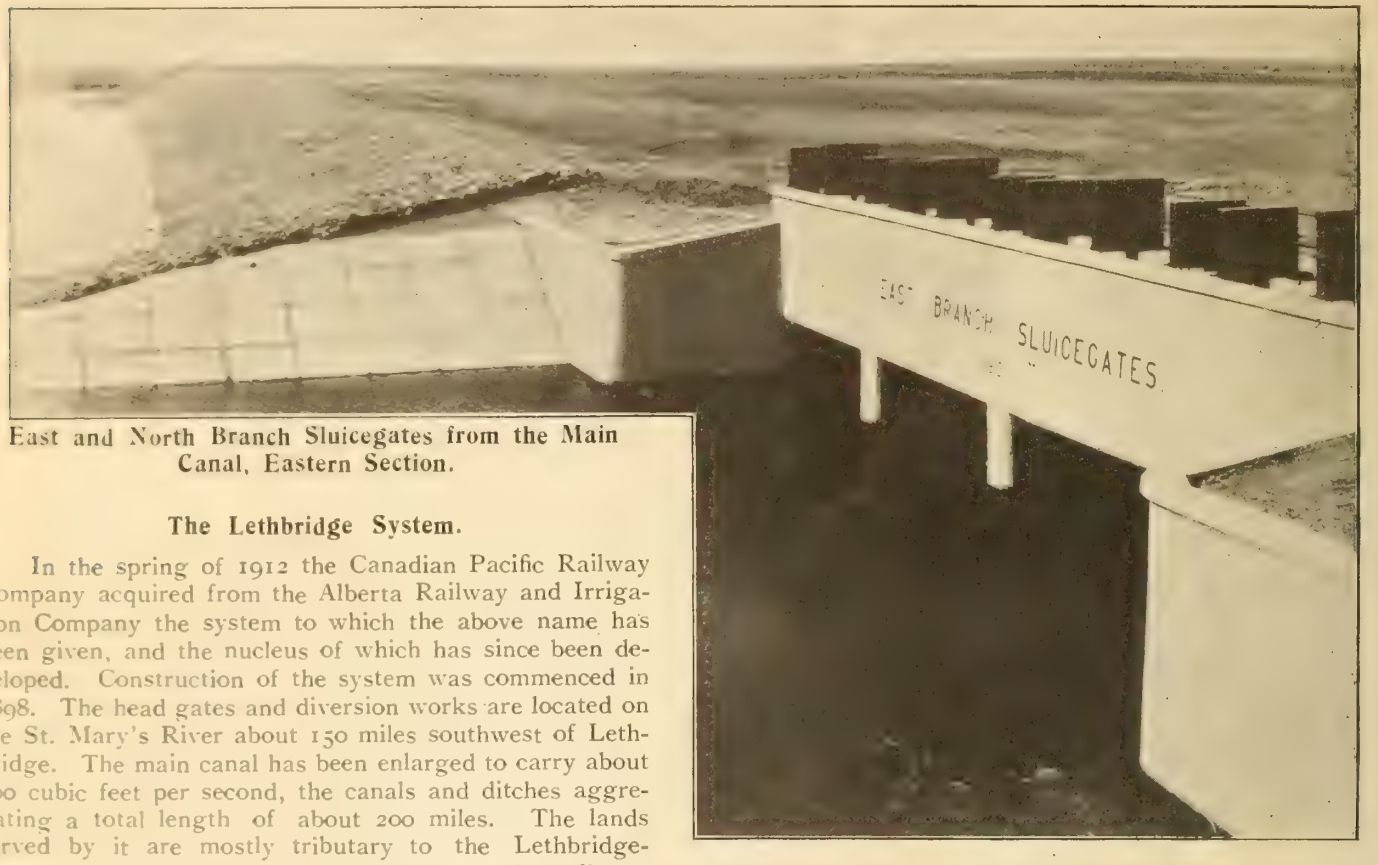
The Lake Newell reservoir outlets into a canal about 5 miles long, with 40 ft. bed width and 7 ft. depth of water. At its easterly end it discharges into a large reinforced concrete flume about 10,500 ft. in length, known as the Brooks Aqueduct, and possessing several very unique features which will be described later on. It delivers water to a canal serving north and south of the Bantry Hills. This Bantry Canal, until it forks, carries 7½ ft. of water and is about 45 ft. bed width. It has an eastern branch 20 ft. wide carrying 5½ ft. of water.



A Wood-Stave Syphon in the Western Section.

The system serving the eastern section is thus shown to be a very extensive undertaking, involving a number of large and important structures, the details of the construction of which had to be worked out with the greatest possible care. There are about 2,500 miles of canals as follows: main canal, 5 miles; secondary canals, 475

miles; distributing ditches, 2,020 miles. The earth work in connection with the construction of these canals amounted to over 20,000,000 cubic yards. Besides the two most interesting features to be dealt with below, there are drops, head gates, flumes, syphons, etc., to attract worthy attention from an engineering point of view.



East and North Branch Sluicegates from the Main Canal, Eastern Section.

The Lethbridge System.

In the spring of 1912 the Canadian Pacific Railway Company acquired from the Alberta Railway and Irrigation Company the system to which the above name has been given, and the nucleus of which has since been developed. Construction of the system was commenced in 1898. The head gates and diversion works are located on the St. Mary's River about 150 miles southwest of Lethbridge. The main canal has been enlarged to carry about 800 cubic feet per second, the canals and ditches aggregating a total length of about 200 miles. The lands served by it are mostly tributary to the Lethbridge-Magrath and Lethbridge-Chin branches of the railway.

The Horse Shoe Bend Dam.

Owing to its attractive design and its many interesting details, this dam, frequently called the Bassano Dam, has received wide publicity in the engineering press since its completion three years ago. Only its most essential features will accordingly be mentioned here.

As stated, it admits water to the eastern section of the Irrigation Block from the Bow River at Bassano. The sills of the canal head gates are about 34½ ft. above the previously existing level of low water in the river at this point. The dam raises the water an additional 11 ft. above these sills, enabling the system to command a much larger area of land than it otherwise would, and reducing the quantity of material that had to be removed from the main canal cut, by a considerable amount.

The dam is a composite structure consisting of a long and high earthen embankment on the south bank of the river, and a reinforced concrete spillway in the existing river channel, connected at its northerly end with the

General View of the Bassano Dam and Headgates of the Main Canal, Eastern Section.

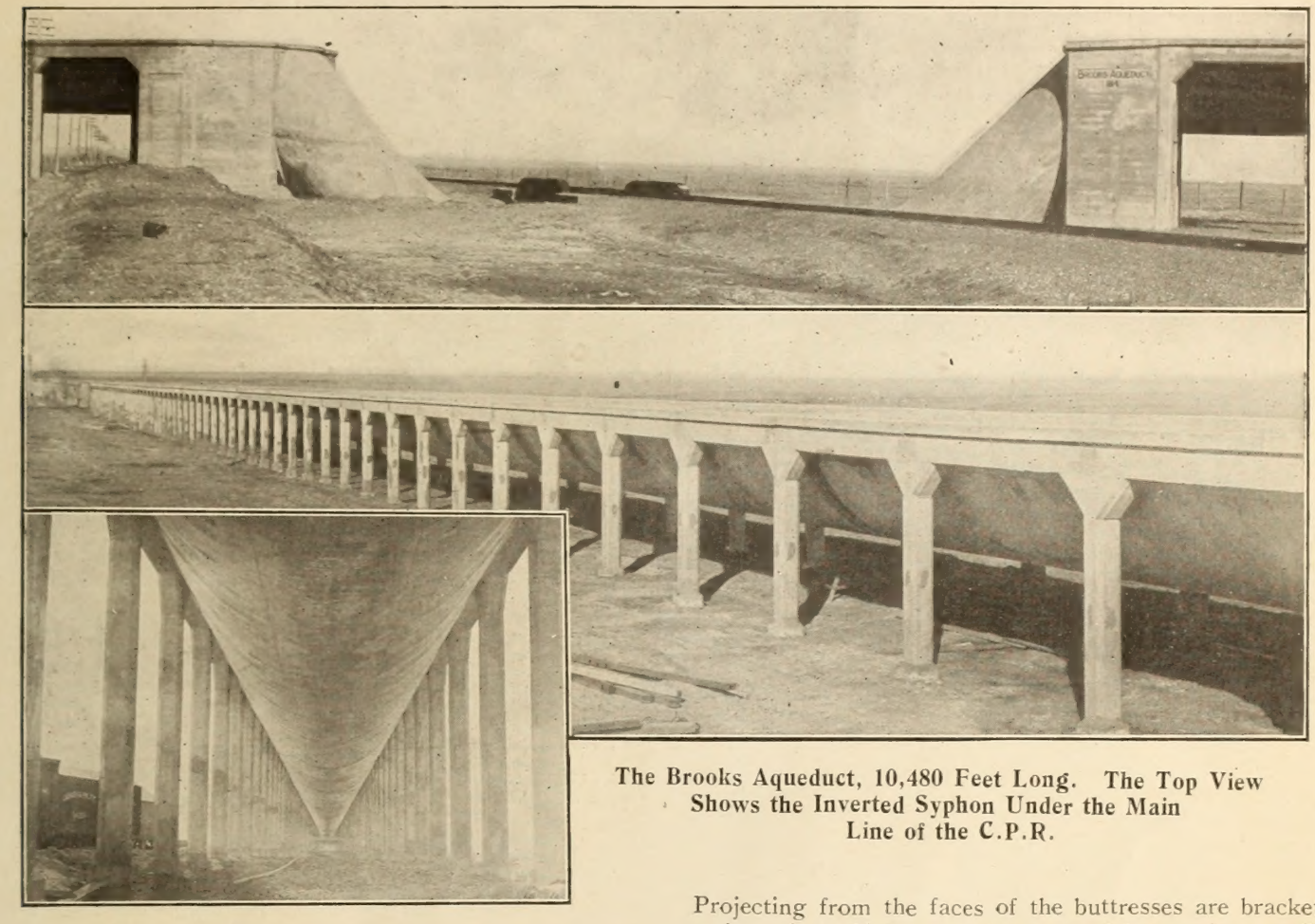
canal head gates. The structure is illustrated to advantage in the accompanying views.

The earthen embankment has a maximum height of about 45 ft., a total length of over 7,000 ft., and a width of base of 350 ft. at its highest point. It contains about 1,000,000 cubic yards of material. The wetted slope is 4:1 and the dry slope 3:1. It has a top width of 32 ft. with a free-board of 9 ft. above normal water level. Its upper slope is paved with concrete slabs. There is an extensive underdrainage system.

The spillway allows over its crest 100,000 second-feet of water without raising the surface of the pool more than 13 ft. above the crest. This required in the design a free length of weir of about 600 ft., but to allow for end contraction on account of the piers necessary to support the movable crest, an aggregate length of 650 ft. between piers was decided upon.

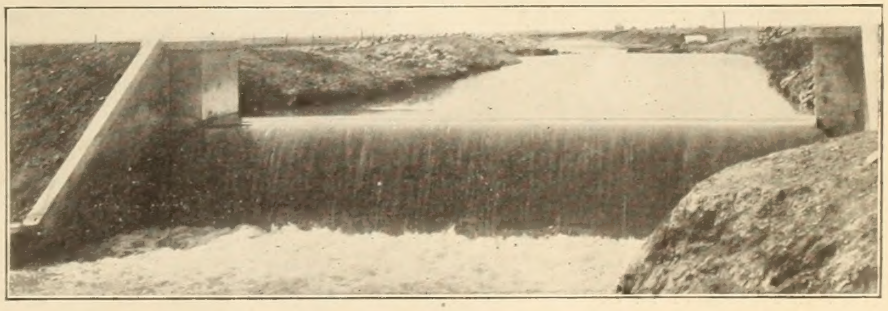
As the crest of the dam coincides in elevation with the sills of the canal head gates, the additional depth of 11 ft., for which the canal was designed, is provided by a movable crest over the entire length of the spillway. This is for service in time of extreme flood. It is divided into 24 sections, and supported between piers, giving 27 ft. clear spans. The openings are regulated by structural steel gates. The buttresses are spaced at 15-ft. centres, with every second buttress carried up in the form of a bridge pier, giving a clear span of 27 ft., as stated.

The spillway proper is a reinforced concrete structure of the Ambursen type, consisting of a heavy floor built upon the bed of the stream, with suitable cut-off walls at its up-stream and down-stream edges; upon this floor are erected parallel buttresses of substantially triangular face with a slope on the up-stream edge of 45 degrees.



The Brooks Aqueduct, 10,480 Feet Long. The Top View Shows the Inverted Syphon Under the Main Line of the C.P.R.

Projecting from the faces of the buttresses are brackets or haunches which support concrete slabs running parallel to the up-stream edges of the buttresses and forming a deck which terminates in line with the top of the buttress in a curved crest, which passes down over the down-stream face of the buttresses in the form of an apron suitably curved to correspond as nearly as possible with the path of the overfalling water. In front of the dam the floor is carried down stream for a distance of about 90 ft., forming a tumbling hearth. At both edges of the structure, as well as at the centre, heavy cut-off walls are carried down to the clay and bonded to the body of the carpet.

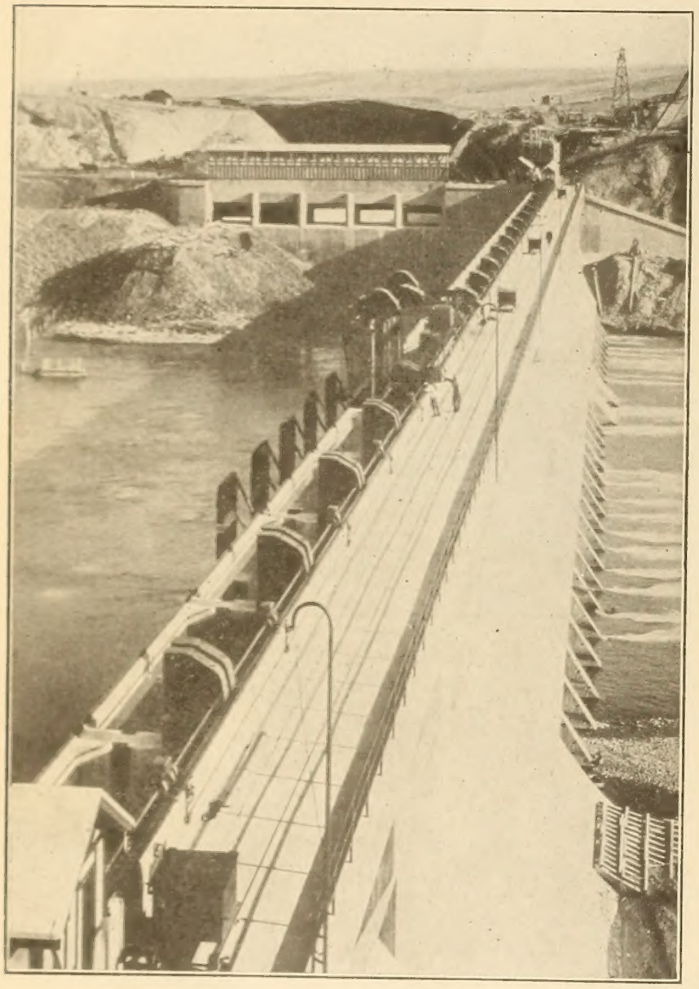


A Typical Drop in the Weed Creek Canal.

The structure is 720 ft. in length between abutments with a maximum height of 40 ft. to the overflow crest, not including the additional 11 ft. retained by the gates. It contains about 40,000 cubic yards of concrete and 2½ million pounds of reinforcing steel.

The abutments connecting the spillway with the earth dam are in the form of reinforced concrete retaining walls of the counterfort type.

A power plant comprising vertical turbines with direct connected generators is housed inside the dam, providing power for gate operation and for lighting.



Crest of Bassano Dam, Headgates and Main Canal in the Background.

The canal head gates form an integral part of the spillway structure at its northerly end and consist of five openings 20 ft. long, controlled by electrically operated Stoney sluices. The main canal into which this discharge empties (3,800 cu. ft. per second) has a bed width of 70 ft. and carries 11 ft. of water.

The Brooks Aqueduct.

Part of the water which reaches the Lake Newell reservoir after its 30-mile course from Bassano through the east branch canal, feeds the Bantry Canal, which irrigates 135,000 acres of land. About 2½ miles beyond the lake it is necessary to carry the water across a long flat valley on the summit of the water shed between the Bow and the Red Deer Rivers. This is accomplished by a reinforced concrete flume known as the Brooks aqueduct, completed August 31st, 1914. Its construction marked an interesting departure in the matter of water transportation. It is the first aqueduct in which the hydrostatic catenary, or elastic curve, has been adopted for the shape of the water section. This form was chosen as the most suitable, as it gives a maximum hydraulic radius for the given area, and a consequent low friction head. Structurally it is very economical since, when full, the shell is in simple tension, free from shear and bending moments. Mr. H. B. Muckleston, assistant chief engineer, Department of Natural Resources of the Canadian Pacific Railway, is responsible for the adoption of this unique design.

The curved shell which, as stated, has been constructed of reinforced concrete, is suspended between horizontal girders at 23 ft. ½ in. centres, the whole being supported by a reinforced concrete trestle, made up of two lines of columns spaced 20 ft. c. to c. longitudinally, and varying in bracing according to the height, which in itself varies from 24 to 60 ft. The aqueduct is 10,480 ft. in length with a total fall of 4.85 ft. The water cross-section is 126 sq. ft., carrying 900 cu. ft. per second on a grade of 0.00038, at a velocity of 7.146 ft. per second, the hydraulic radius being 4.37 ft.

An interesting problem existed in joining up the Bantry Canal with the aqueduct, which meant reducing the sectional area from 456 sq. ft. to 126 sq. ft., and increasing the velocity from 2 ft. per second to 7.146 ft. per second. This reducing channel is 150 ft. long with varying slopes in its initial sections until its flat concrete bottom gradually disappears at the entrance of the flume section.

Another interesting feature arose from the necessity of crossing the main line of the Canadian Pacific Railway, there being insufficient clearance for an overhead structure. Here the water is carried underneath the track by means of an inverted syphon, which gradually tapers with its decreasing elevation to a reduced section which increases the velocity of the water from 7.14 ft. per second to 12.25 ft. per second on the principle of the venturi tube. This design required less excavation under the tracks and assured better drainage. The gradual expansion of the section as it rises at the outlet is similar to the descent, the water entering the flume again at the same velocity with which it enters. The prevention of eddies and consequent loss of head in the syphon in addition to provision for hydrostatic pressure, and the usual stresses and moments, led to some most interesting details of design, arising out of extensive preliminary investigation. When the water was turned on last September the syphon remained perfectly watertight under its full pressure.

In the construction of the Brooks aqueduct some 25,000 cubic yards of concrete and about 4,000,000 pounds of reinforcing steel were used.